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DATA ON THE NUMBER OF SOMITES COMPARED WITH AGE IN THE WHITE RAT.

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The following report containing data on the relation between age and the number of somites in the rat is based on materials secured from the rat colony of the Department of Anatomy at the University of California during the summers of 1925 and 1926.

The material was collected at the suggestion of Dr. Herbert M. Evans with the object of studying the whole problem of the origin of the neural tube and the relation of the neural crest and placodes to the origin of the cerebral ganglia.

The publication of an extensive paper by Adelman ('25) on the neural folds and cranial ganglia of the rat, resulted in a change in the original program, the senior author being responsible for the later stages in development especially those involving the structure and possible contribution of the epibranchial placodes to the cerebral ganglia.

The effort to arrange a graded series of embryos, in order to follow the growth and differentiation of some particular structure which cannot be followed except in fixed material, always presents the uncertainty as to whether the series is as complete as possible and whether it is possible to predict the stage of growth and differentiation on some definite standard such as age or number of somites. When this can be done the grading of a series becomes a simple matter. When the variation between such criteria as age, length, weight and number of somites is pronounced then the problem of arranging a series to illustrate the growth of some particular body structure lacks the element of predictability largely, and the structure must be followed more or less independently and the uncer-

tainty of stating that any particular phase of growth or differentiation is absent is very great.

In order to arrange embryos in a series that would be as nearly continuous as possible it was decided to base the series on the age of embryos estimated from the time of deposition of the sperm plug. The mating was done by Dr. Evans after the proper stage in the oestrus cycle had been determined from vaginal smears. Extreme care was exercised that the estimated time of deposition of the sperm plug should not vary in the records by more than five minutes although the age as recorded in the tables is given to the nearest hour. This was accomplished by examining each female after coitus at intervals of not more than five minutes. After the deposition of the sperm plug as determined by vaginal examination the female was removed from the breeding cage.

All males used in the mating were tested for fertility prior to use for this series, but females had not been previously mated. The extreme care exercised in the choice of both parents as well as the accuracy of the time of deposition of the sperm plug seems to the writers to reduce to a minimum whatever objections there might be to using the deposition of the sperm plug as a means of estimating the age of embryos. Whatever defect this method may have, due to variation in the time of ovulation and fertilization as compared with the time of deposition of the sperm plug, it is a convenient and easily controlled method and gives a definite standard from which to make comparisons.

The use of females that had not been mated previously may be open to some objection since in the rodents at least the variations in growth and differentiation and possibly in age may vary more with first matings than with later matings.

A characteristic of the Berkeley colony should be noted although it is not apparent why it should effect the variations between age and number of somites. The colony is descended from a cross between an albino rat from the Wistar colony and a wild gray rat, Swezey (26-28). The Berkeley colony shows two different chromosome counts, 42 and 62 with haploid numbers of 21 and 31 respectively, 42 being the number for both the albino and wild gray rat.

There is a further possibility that variations between the number of somites and age as estimated from the time of deposition of the sperm plug might be due to differences in time

of fertilization and this variation might be greater in first matings than in subsequent matings.

The observations of Long and Evans ('22) indicate that this difference as estimated by variations in ovulation is slight since ovulation occurs in first matings throughout a period of 12 hours, i.e., the last 12 hours of the II and III stages of the oestrus cycle, and following littering during a period of 8 hours, i.e., between 16 and 24 hours after littering, so that if one can estimate age by ovulation there should not be any marked variation in embryos due to first matings providing this variation is not greater between embryos of different mothers than between embryos of the two horns from the same uterus or between embryos from the same horn of the uterus. The four hours more or less assumed for the sperm to traverse the oviduct would normally transpire before ovulation was completed since the female accepts coitus during the II period of oestrus, i.e., presumably during the early part of the 30 hours involved in the II and III stages of the oestrus cycle and would not seem to furnish a basis for differences between age and number of somites.

While the collection of material was going on, examination made on single litters under the dissecting microscopes showed such variations in size and number of somites that it became apparent that arranging a graded series based on age as estimated from the deposition of the sperm plug would present serious difficulties and that these same difficulties might be encountered in the effort to describe almost any phase of the formation of neural crest, ganglia, or placodes and their relation to each other.

In the paper by Adelman ('25) cited above the conclusion was reached that there is no evidence for the contribution of cells from the epibranchial placodes to the ganglia of the VII, IX and X nerves in the white rat. Notwithstanding, the difficulties of following placodal cells as distinct from mesenchymal cells in birds and mammals, a difficulty which has been recognized for many years, there seemed to be a possibility for error in this case owing to difficulties of securing a series that was fairly continuous for any given structure when either age or number of somites was used as a criterion for determining where to look for a given step of the process if present.

Since marked variations occur not only between litters of the same age but between embryos of the same litter, both

between embryos of the right horn as compared with the left and even within the same horn these variations even with the precautions mentioned above make it evident that any effort to predict what could be expected to occur in any given case based on age or number of somites might be hazardous to say the least.

TABLE I.
ACCOUNTING FOR ALL EMBRYOS.

AGE Days-Hrs.	MOTHER'S NUMBER	LEFT UTERUS								RIGHT UTERUS									
		L1	L2	L3	L4	L5	L6	L7	L8	R1	R2	R3	R4	R5	R6	R7	R8	R9	
10-12	W 2355	r	11	11	n	7	r	.....	.....	n	6	r	.....	.....	.....	.....	.....	.....	.....
10-13	W 2221	r	8	13	i	r	9	12	.....	8	11	.....	.....	.....	.....	.....	.....	.....	.....
10-16	W 2354	n	6	8	23	26	8	10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10-16	BH 2500	i	11	.....	.....	.....	.....	.....	.....	12	8	12	12	13	.....	.....	.....	.....	.....
10-17	BH 2551	9	9	9	.....	.....	.....	.....	.....	11	11	r	9	n	n	.....	.....	.....	.....
10-17	W 2573	19	4	12	.....	.....	.....	.....	.....	10	n	13	n	i	14	15	.....	.....	.....
10-17	GH 2226	r	r	14	13	.....	.....	.....	.....	r	r	n	r	7	26	r	.....	.....	.....
10-17	W -12	15	15	14	15	16	.....	.....	.....	13	15	15	15	15	14	14	.....	.....	.....
10-17	B 2327	12	14	12	13	11	.....	.....	.....	13	13	13	13	12	.....	.....	.....	.....	.....
10-17	G 2326	16	8	13	13	10	16	.....	.....	r	11	11	14	.....	.....	.....	.....	.....	.....
10-18	B 2165	16	i	17	i	12	i	n	.....	r	14	16	n	15	17	.....	.....	.....	.....
10-18	W 2258	r	8	6	i	n	n	n	r	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10-18	W 2151	13	.....	.....	.....	.....	.....	.....	.....	13	r	14	13	14	14	14	r	1	.....
10-18	W 2520	17	9	17	17	.....	.....	.....	.....	n	n	18	n	13	18	n	.....	.....	.....
10-19	W 2237	12	12	r	15	r	17	r	15	n	15	r	r	.....	.....	.....	.....	.....	.....
10-22	W 2586	15	9	9	8	i	n	.....	.....	13	12	i	n	.....	.....	.....	.....	.....	.....
10-22	W 2273	15	r	19	18	18	.....	.....	.....	18	r	n	n	.....	.....	.....	.....	.....	.....
10-22	B 2342	9	r	6	.....	.....	.....	.....	.....	n	14	14	13	n	.....	.....	.....	.....	.....
10-23	B 2277	n	12	17	15	.....	.....	.....	.....	15	15	17	17	16	.....	.....	.....	.....	.....
10-23	B 2577	16	.....	.....	.....	.....	.....	.....	.....	17	8	15	18	14	13	.....	.....	.....	.....
10-23	W 2172	i	17	18	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11-00	W 2282	r	r	r	.....	.....	.....	.....	.....	r	15	17	14	r	14	15	15	.....	.....
11-00	BH 2198	14	17	.....	.....	.....	.....	.....	.....	i	10	.....	.....	.....	.....	.....	.....	.....	.....
11-02	GH 8424	21	22	21	21	r	.....	.....	.....	21	20	22	22	21	.....	.....	.....	.....	.....
11-02	GH 8975	r	21	22	21	.....	.....	.....	.....	17	r	22	19	r	.....	.....	.....	.....	.....
11-04	W 8400	25	26	26	23	26	.....	.....	.....	26	23	24	25	r	26	26	.....	.....	.....
11-06	GH 8474	.....	.....	.....	.....	.....	.....	.....	.....	18	r	r	r	18	.....	.....	.....	.....	.....
11-08	B 8415	23	r	28	.....	.....	.....	.....	.....	25	24	25	24	28	23	.....	.....	.....	.....
11-09	W 8699	.....	.....	.....	.....	.....	.....	.....	.....	25	i	20	21	.....	.....	.....	.....	.....	.....
11-10	W 2162	22	23	r	25	23	.....	.....	.....	23	26	n	r	24	n	.....	.....	.....	.....
11-10	B 2271	28	30	29	26	28	29	31	.....	i	21	27	28	28	.....	.....	.....	.....	.....
11-11	W 8426	28	27	25	28	.....	.....	.....	.....	i	26	i	28	29	28	28	.....	.....	.....
11-11	W 2142	27	27	26	i	27	.....	.....	.....	24	18	27	25	27	.....	.....	.....	.....	.....
11-11	W 2357	23	25	26	26	n	i	26	.....	23	27	14	.....	.....	.....	.....	.....	.....	.....
11-12	W 2353	i	25	i	n	n	.....	.....	.....	r	27	28	.....	.....	.....	.....	.....	.....	.....
11-14	BH 2219	22	i	r	21	21	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11-15	GH 2214	i	17	26	26	25	.....	.....	.....	25	17	n	21	28	.....	.....	.....	.....	.....
11-16	W 2572	n	27	27	n	n	28	26	.....	24	28	27	.....	.....	.....	.....	.....	.....	.....
11-17	G 2206	25	27	27	r	r	26	.....	.....	25	i	25	28	.....	.....	.....	.....	.....	.....
11-18	BH 2507	i	17	r	24	28	.....	.....	.....	24	24	25	24	24	.....	.....	.....	.....	.....
11-18	B 2194	24	27	25	26	n	28	.....	.....	25	26	26	26	27	.....	.....	.....	.....	.....
11-18	BH 2197	26	i	27	24	28	.....	.....	.....	26	26	26	i	.....	.....	.....	.....	.....	.....
11-20	W 2180	r	27	r	r	.....	.....	.....	.....	27	27	r	26	29	25	r	28	.....	.....
11-20	W 8426	28	27	i	28	.....	.....	.....	.....	i	26	25	28	29	28	28	.....	.....	.....

KEY: r—resorption; i—injured; n—not in our lot. L1 and R1 embryo^s nearest ovary.

As a preliminary to the study of the variability in the formation of the placodes for instance as compared with age or number of somites the following tables are presented without any attempt to interpret them statistically except to call attention to their value as a basis for prediction since that is the practical value which such tables have when a series of embryos is arranged with a view to following any given structure in growth and differentiation.

Complete data are given in Table I showing the age to the nearest hour, the position of the embryo in the right or left

TABLE II.
SUMMARIZING DATA IN TABLE I.

AGE Days-Hours	TOTAL NO. EMBRYOS	NOT IN OUR LOT	INJURED	RESORBED	NUMBER OF SOMITES IN EMBRYOS COUNTED
10-12	9	2	.....	3	6-7-11-11
10-13	9	.....	1	2	8-8-9-11-12-13
10-16	14	1	1	.....	6-8-8-8-10-11-12-12-12-13-23-26
10-17	62	5	1	8	4-7-8-9-9-9-9-10-10-11-11-11-11-11- 12-12-12-12-13-13-13-13-13-13- 13-13-13-14-14-14-14-14-14-15- 15-15-15-15-15-15-16-16-16-19- 26
10-18	42	9	5	5	6-8-9-12-13-13-13-13-14-14-14-14- 14-15-16-16-17-17-17-17-18-18
10-19	12	1	.....	5	12-12-15-15-15-17
10-22	27	6	2	3	6-8-9-9-9-12-13-13-14-14-15-15-18- 18-18-19
10-23	19	1	1	.....	8-12-13-14-15-15-15-16-16-17-17- 17-17-17-18-18
11-00	15	.....	1	5	10-14-14-14-15-15-15-17-17
11-02	19	.....	.....	4	17-19-20-21-21-21-21-21-21-21-22- 22-22-22-22
11-04	12	.....	.....	1	23-23-24-25-25-26-26-26-26-26-26
11-06	5	.....	.....	3	18-18
11-08	9	.....	.....	1	23-23-24-24-25-25-28-28
11-09	4	.....	1	.....	20-21-25
11-10	23	2	1	2	21-22-23-23-23-24-25-26-26-27-28- 28-28-28-29-29-30-31
11-11	31	1	4	.....	14-18-23-23-24-25-25-25-26-26-26- 26-26-27-27-27-27-27-27-27-28-28- 28-28-28-29
11-12	8	2	2	1	25-27-28
11-14	5	.....	1	1	21-21-22
11-15	10	1	1	.....	17-17-21-25-25-26-26-28
11-16	10	3	.....	.....	24-26-27-27-27-28-28
11-17	10	.....	1	2	25-25-25-26-27-27-28
11-18	30	1	3	1	19-24-24-24-24-24-24-25-25-25- 26-26-26-26-26-26-26-27-27-27- 28-28-28
11-20	23	.....	2	5	25-25-26-26-27-27-27-27-28-28-28- 28-28-28-29-29
Totals.....	408	35	28	52	292 Embryos Counted.

horn of the uterus, the number of resorptions, the number of embryos injured so that counts of somites could not be made and the number of embryos not in our collection.

Table II is a summary of the data in Table I. A total of 408 embryos was found in the 44 litters. Of this number 35 embryos were sent to another university and no data are

TABLE III.
SHOWING MEANS AND VARIATION FOR EACH AGE.

AGE Days-Hrs.	NUMBER OF LITTERS	NUMBER EMBRYOS COUNTED	MEANS	MAXIMUM VARIATION		STANDARD DEVIATION	COEFFICIENT OF VARI- ATION—%
				ALL EMBRYOS	ONE LITTER		
10-12	1	4	8.7	6-11	6-11	2.8	32
10-13	1	6	10.2	8-13	8-13	1.9	19
10-16	2	12	12.4	6-26	6-26	5.8	47
10-17	6	48	12.9	4-26	7-26	3.3	26
10-18	4	23	14.1	6-18	9-18	3.1	22
10-19	1	6	14.3	12-17	12-17	1.2	8
10-22	3	16	13.1	6-19	6-14	3.9	30
10-23	3	17	15.2	8-18	8-18	2.4	16
11-00	2	9	14.6	10-17	10-17	1.9	13
11-02	2	15	20.9	17-22	17-22	1.3	6
11-04	1	10	25.3	23-26	23-26	1.2	5
11-06	1	2	18.0	18-18	18-18	.0	0
11-08	1	8	25.0	23-28	23-28	1.9	8
11-09	1	3	22.0	20-25	20-25	2.2	10
11-10	2	18	26.2	21-31	21-31	2.9	11
11-11	3	26	25.6	14-29	14-27	3.2	12
11-12	1	3	26.7	25-28	25-28	1.2	4
11-14	1	3	21.3	21-22	21-22	.5	2
11-15	1	8	23.1	17-28	17-28	4.0	17
11-16	1	7	26.7	24-28	24-28	1.3	5
11-17	1	7	26.1	25-28	25-28	1.1	4
11-18	3	25	25.4	19-28	19-28	1.9	7
11-20	2	16	27.2	25-29	25-29	1.2	4
23 Ages	44	292				Av. 2.2	Av. 13%

furnished in regard to them. They are marked "n" in Chart I. Unfortunately 28 embryos were injured in excision or handling, so badly that the somites could not be counted. They are designated "i" in Chart I. Fifty-two cases of definite resorption were found in the 408 cases observed and they are designated "r" in Chart I. Finally an accurate count of somites in 292 embryos or about 75% of all uterine enlargements was secured. A very wide difference in number of somites at many of the different ages should be noted. For example, at 10 days 17 hours the somite count ranges from 4 to 26, giving us an extreme variation. At 10 days 16 hours the range

is from 6 to 26 somites, and similar variations are found at a number of other ages.

In Table III the arithmetic mean number of somites for all embryos of each age is given. It will be noticed that these means would form quite an irregular curve. It is probable that the means from many thousands of cases would form a much more gradual curve and show a definite gradual growth. However, there are still wide variations within the group at any one particular age.

The standard deviations for each age have been computed and are shown in Chart III. These range from 0 at 11 days 6 hours, at which age we have only two embryos, each having a count of 18 somites, to 5.8 at 10 days 16 hours. The significance of this standard deviation of 5.8 can be appreciated much more readily if the coefficient of variation is computed. We find that this gives us the enormous coefficient of 47%. Although that represents our extreme variation for any one age, nevertheless, we have several other large coefficients and an average coefficient of 13%. This means that on the average each embryo contains a number of somites approximately 13% more or less than the mean for its age.

If we are liable to get coefficients of variation up to 47% for one particular age and can count on at least a deviation from the mean of 13% which would mean 2 or 3 somites and might mean as many as 12 or 13 somites, it seems reasonable to conclude that one is hardly justified in assigning a certain number of somites to an embryo of a certain known age. Further, in view of the fact that we have variations within a single litter of 7 to 26 somites (age 10 days 17 hours), it appears that one cannot be even reasonably sure of the number of somites in an embryo of any known age. The further inference is suggested that in the growth and differentiation of a particular structure when compared with a standard such as age, length, weight or number of somites in the rat, a wide range of variation might be encountered and might increase the difficulty of securing a complete series of growth changes.

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HYDROGEN ION CONCENTRATION AND TITRATABLE ACIDITY OF TOMATOES AND THEIR RESISTANCE TO FUSARIUM WILT.*

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INTRODUCTION.

The question of the nature of the resistance or susceptibility of plants to various diseases is one of the fundamental problems with which workers in the field of plant pathology have to deal. The literature on the subject is extensive and varied. Many theories have been advanced to account for the striking differences of response among varieties of certain species of plants to the attacks of parasitic organisms. One of the numerous theories suggested is that the acidity of the sap may be a determining factor in the resistance or susceptibility of plants to certain diseases.

The present paper is a report of work on the relation between hydrogen ion concentration and titratable acidity and the resistance of tomatoes to *Fusarium* wilt.

1. HYDROGEN ION CONCENTRATION AND RESISTANCE.

Review of Literature.

Hawkins and Harvey (4) found that the H-ion concentration of potato varieties was not related to their property of resisting the attack of *Pythium deBaryanum*. Hurd (5) made extensive investigations of the H-ion concentration of several varieties of wheat and concluded that there was no correlation between this factor and their resistance or susceptibility to certain diseases. Tims (11) investigated the pH of cabbage varieties resistant and susceptible to *Fusarium* wilt and found that, although there were some variations between the varieties, the differences were not large enough to be significant. Smith and Quirk (10) found that certain begonias which possessed high

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acidity were very resistant to crown gall infection. Furthermore, if the begonia juice was pressed out and neutralized, the crown gall organism grew very well in it. They also state that all plants known or suspected of being immune to crown gall have been found, as far as tested, to have juice more acid than pH 5.7, which is the limit of growth of *Bact. tumefaciens* in bouillon media and in acid juice.

Methods.

Two precautions were exercised in order that the H-ion concentration of all plants might be as equally influenced by environmental conditions as possible. Since there is a possibility that wilt infection might alter the normal acidity of the plants, they were grown on "wilt-free" soil, and were, in addition, clinically examined for incipient wilt infection before being used as a source of juice for the determinations.

Haas (3), Truog (12) and others have reported that the reaction of the soil in which certain plants are growing influences their hydrogen ion concentration. Care was taken, therefore, to test the soil of all the plots in which the plants were grown and it was found to be fairly uniform, about pH 7.20.

For the determinations of pH and total acidity the plants were brought into the laboratory and portions of the stems cut into short pieces. The pieces were washed and wiped dry, wrapped in cheese cloth, and placed in a 3-inch pipe cap. Another pipe cap, slightly smaller than the first, was set over them. The cylinder and piston thus formed by the two caps were placed under the screw of a letter press mounted on a vertical frame and pressure was applied. About 25 to 30 cc. of juice were squeezed from the younger parts of tomato stems at one pressing. The whole operation required about three minutes.

Actual and titratable acidity were determined electrometrically. The apparatus consisted of a quinhydrone electrode, a Leeds and Northrup type K potentiometer and type R galvanometer, a saturated calomel cell, and a two percent agar bridge saturated with KCl. The system was frequently checked with M/20 potassium acid phthalate solution (ph 3.97) as recommended by Clark (1) to determine its accuracy.

Ten cubic centimeters of the juice were transferred to a beaker and .2-.3g. of quinhydrone added and stirred. In two or three minutes equilibrium was reached and a reading made.

The adaptability of the quinhydrone electrode for determining the pH and titratable acidity of the tomato juice was ascertained by comparing it with the standard hydrogen electrode. Determinations of the pH values and of the titratable acidity of comparable samples of expressed tomato juice

TABLE I.
HYDROGEN ION CONCENTRATION IN pH UNITS OF DIFFERENT PARTS OF WILT
RESISTANT (R) AND SUSCEPTIBLE (S) TOMATO PLANTS.

	Bonny Best S	Marglobe R	Norton R
Soil.....	7.20	7.20	7.20
Fiber roots.....	5.71	5.85	5.80
Large roots:			
Central cylinder.....	6.15	5.95	6.20
Cortex.....	5.44	5.58	5.45
Root stock			
Central cylinder.....	6.20	5.90	5.95
Cortex.....	5.61	5.60	5.55
Stem (at ground level)			
Pith.....	5.97	5.91	5.94
Rest of stem.....	5.73	5.77	5.80
Stem (one foot above ground)			
Pith.....	5.97	5.93	5.96
Rest of stem.....	5.97	5.88	5.90
Stem (two feet above ground)			
Pith.....	5.65	5.70	5.68
Rest of stem.....	5.65	5.70	5.69
Stem tip.....	5.58	5.61	5.64
Petioles.....	5.58	5.56	5.60
Leaf blades.....	6.06	6.01	5.98

made with both the hydrogen electrode and the quinhydrone electrode gave results agreeing very well. The differences between the pH values of the expressed juice obtained by the two methods were in the second decimal place as a rule. The titrations were carried to pH 7.00, as it was found that the quinhydrone electrode was not accurate in solutions less acid than this.

Results.

Table 1 summarizes the results of five determinations of the hydrogen ion concentration of various parts of mature tomato plants.

Fusarium lycopersici Sacc. usually enters the plant through the roots. It was thought that an investigation of the pH of the root systems of resistant and susceptible varieties might show some interesting differences but, as the results recorded in Table 1 show, this was not the case.

The data show that the different tissues of the tomato plants examined did not have the same H ion concentration.

TABLE II.

HYDROGEN ION CONCENTRATION IN pH UNITS OF THE EXPRESSED JUICE OF WILT RESISTANT AND SUSCEPTIBLE VARIETIES OF TOMATOES OF DIFFERENT AGES.

Stage of Growth of Plants	Bonny Best (S)	Earliana (S)	Norton (R)	Norduke (R)	Marglobe (R)	La. Pink (R)
Seedlings (4").....	6.10	6.08	6.11	6.12	6.23	6.09
Transplants (9").....	6.07	6.05	6.02	6.05	6.09	6.04
Transplants (15").....	5.92	5.87	5.83	5.79	5.81	5.80
Vining begun.....	5.83	5.79	5.75	5.81	5.70	5.73
First fruit setting.....	5.70	5.72	5.69	5.77	5.72	5.70
Mature fruit on vines.	5.38	5.40	5.46	5.40	5.42	5.43

However, similar tissues in the three varieties had about the same H ion concentration and therefore need not be considered further so far as wilt resistance is concerned.

Table 2 shows the pH values of the juice of wilt resistant and susceptible varieties of tomatoes at various stages of development. Each pH value given is an average of several determinations. All the plants except the youngest seedlings, which were started in flats in the greenhouse, were grown under field conditions.

The results recorded in Table 2 indicate that there were no significant differences in hydrogen ion concentration between the varieties used in the experiments at any given stage in the growth of the plants. It is evident, however, that the acidity of the plants increased as the season advanced and as the plants became older. Several factors may be involved in this increase of acidity. Hurd (5) has shown that wheat seedlings may vary

considerably in pH if their environment is changed. The data in Table 2 were taken at various times during the summer from May until September. Environmental conditions changed during that time and these changes may have been partly responsible for the increase. Hurd (6) has also found that there is an increase in the hydrogen ion concentration of wheat plants as they pass through the flowering and later stages. In the present case, since there was a regular progression from lesser to greater acidity as the plants increased in age, it is felt that the age of the plants was an important factor in the change. But, whatever may have been the cause of the increase in the acidity of the plants, all varieties changed to about the same pH values at the same time.

The data in Table 1 and 2 permit the conclusion that in tomatoes there is no correlation between the hydrogen ion concentration of the juice and the susceptibility of the plant to *Fusarium* wilt.

2. TITRATABLE ACIDITY AND RESISTANCE.

Review of Literature.

Although it is evident that the hydrogen ion concentration of the juice is not the factor determining resistance or susceptibility to the wilt disease, it was thought possible that there might be significant differences in titratable acidity between the resistant and susceptible varieties.

Hurd (6, 7) found that the titratable acidity of wheat varieties was not correlated with their degree of resistance or susceptibility to *Puccinia graminis tritici* or to *Tilletia tritici*. Laurent (9) titrated the expressed juice of potato tubers resistant and susceptible to bacterial rot and found no relation between acidity and resistance. On the other hand Kirchner (8) found more titratable acid in two rust resistant and one smut resistant varieties of wheat than in an equal number of susceptible varieties. A more extensive review of the pertinent literature may be found elsewhere (7).

Methods.

The juice from growing stems was ordinarily taken for the determination of titratable acidity. Gustafson (2) found that the younger parts of some plants, although of less actual

acidity, may have a higher total titratable acidity than older portions of the same plants. A few determinations were made with this point in mind and it was found that in some cases the younger parts of the stems had more total titratable acid than the older parts, but in other cases there were no differences. However, in order to standardize the method, only the upper 8-10 inches of the stems were used. The juice was squeezed out by the method already described. Ten cc. constituted a sample which was titrated with .2 cc. increments of N/125 NaOH until the pH of the sample became greater than 7.00. Duplicate determinations were made on all samples.

TABLE III.

TITRATABLE ACIDITY OF TOMATOES TAKEN AT INTERVALS FROM SEEDLING TO FRUITING STAGE IN CUBIC CENTIMETERS OF N/125 NaOH REQUIRED TO NEUTRALIZE 10 CC. OF EXPRESSED JUICE.

Stage of Growth of Plant	SUSCEPTIBLE	RESISTANT			
	Bonny Best	Norton	La. Pink	Marglobe	Norduke
Seedling (5").....	1.15	1.20	1.17	1.23	1.21
Young plant (15").....	.50	.54	.58	.61	.60
First flowers open.....	.46	.49	.48	.48	.52
First fruit setting.....	.48	.53	.60	.55	.52
Mature fruit on vine.....	.40	.43	.38	.42	.46
Average, excluding 5" seedlings.....	.46	.49	.51	.51	.52

Results.

Table 3 shows the average quantities of N/125 NaOH required to bring 10 cc. samples of the expressed juice to neutrality. The figures were obtained by plotting the titration values against the volumes of NaOH necessary to produce them. From the resulting curve the volume of NaOH required to bring the juice to neutrality (pH 7.0) was determined.

The figures given above are the average of a large number of titrations made at intervals throughout the season. The data show that seedlings have greater titratable acidity than older plants and that this factor is not constant during the growth period of the plants, either as the result of ageing or of changing environmental conditions. In so far as differences between the varieties are concerned there are none that can be considered significant from the standpoint of resistance or susceptibility to disease. It is true that Louisiana Pink,

Marglobe, and Norduke had a slightly greater titratable acidity than Bonny Best, but the total acidity of Norton, another resistant variety, was about the same as that of Bonny Best. Furthermore, if the toleration of high H-ion concentration in culture media by *F. lycopersici* and the tendency of this fungus to shift the pH of rather highly buffered acid media toward greater alkalinity can be taken as an index of its ability to tolerate acidity in tomato, the varietal differences found are of little consequence as far as resistance is concerned.

SUMMARY.

1. The hydrogen ion concentration and titratable acidity of five varieties of tomatoes were determined at various stages in the growth of the plants.

2. Neither resistance nor susceptibility of these varieties of tomato to *Fusarium* wilt was correlated with actual or titratable acidity at any stage of growth of the plants.

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THE CRAYFISHES OF WEST VIRGINIA.*

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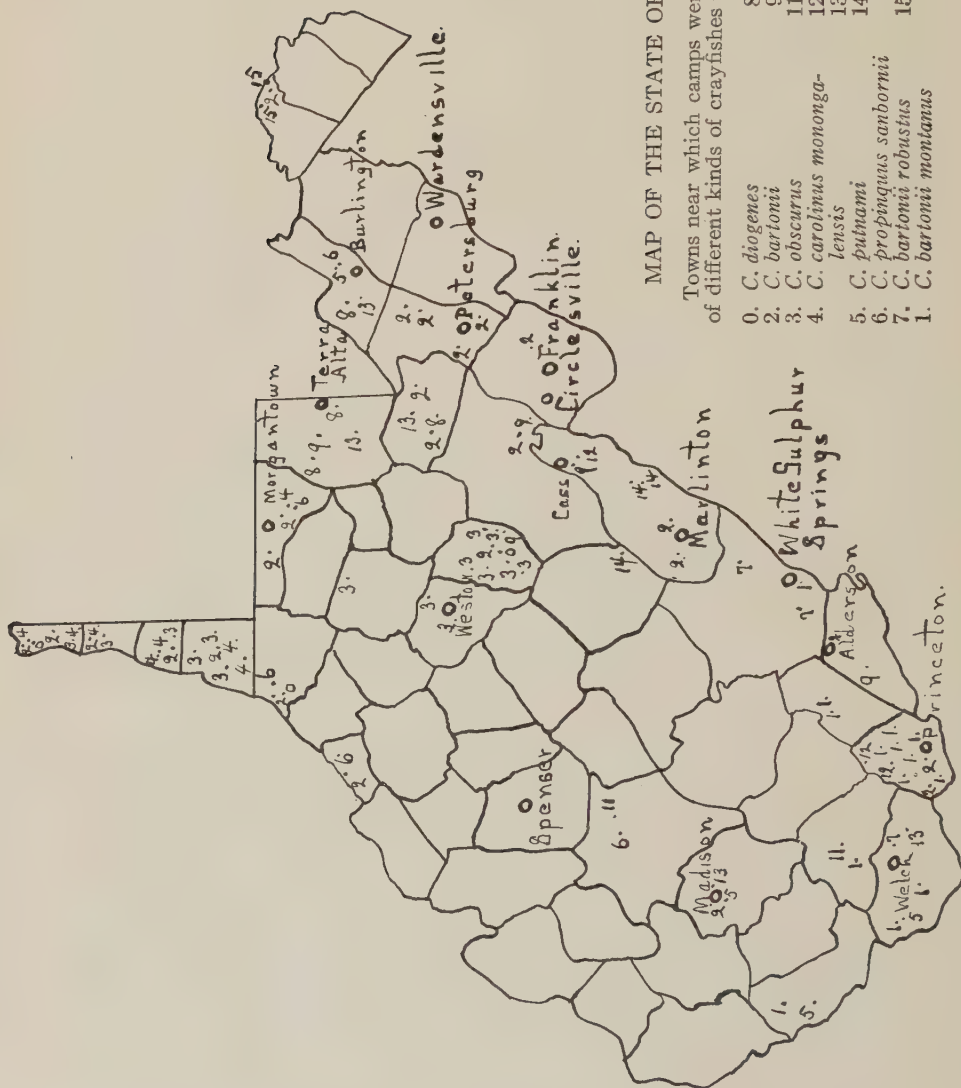
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To the extent that a natural resource of a country has, in the eyes of its people, a distinct economic significance either from a utilitarian viewpoint or from that of a sportsman, in exactly that degree will it receive adequate attention necessary for its preservation. This idea is well exemplified in the case of the fisheries of the State. As soon as the depletion of a species sets in, the demand for information concerning its life history and habits increases.

In the study of crayfishes we cannot say, perhaps, that they possess at the present time any great economic value, positively or negatively. On the other hand, from the point of view of an ecologist, they present almost ideal material for studies of habitat preference, and for investigations to determine the influence of environmental factors on pigmentation. What determines whether a crayfish shall be red or blue or brown? Is it to be explained on a purely genetical basis? Perhaps the factor of age may be significant. Allee ('27) studied the methods of aggregation in the case of the brittle starfish (*Ophioderma brevispina*) and discovered that the aggregations were formed in the main by individual (primary) responses to environmental conditions rather than by social (secondary) impulses. The results of this study substantiate his former conclusions arrived at in his work with land isopods. (Allee '26) What are the types of aggregation, if any, in the case of *Cambarus*? This is an excellent field for research that is in need of elaboration. In this paper the author will give an account of the crayfish-fauna of the State of West Virginia, as complete as possible from the chorological, biological, and ecological standpoint.

This report has resulted from a belief on the part of the author that altogether too little is known concerning the conditions under which crayfishes subsist, more particularly, perhaps, those conditions that will lead to optimum growth and development.

*Contribution from the Zoological Laboratory of West Virginia University.



MAP OF THE STATE OF WEST VIRGINIA

Towns near which camps were located. Distribution of different kinds of crayfishes indicated by numbers.

- | | |
|--------------------------------------|---|
| 0. <i>C. diogenes</i> | 8. <i>C. carolinus carolinus</i> |
| 2. <i>C. bartonii</i> | 9. <i>C. bartonii carinirostris</i> |
| 3. <i>C. obscurus</i> | 11. <i>C. bartonii veteranus</i> |
| 4. <i>C. carolinus monongahensis</i> | 12. <i>C. bartonii longulus</i> |
| 5. <i>C. pulnami</i> | 13. <i>C. carolinus dubius</i> |
| 6. <i>C. propinquus sanbornii</i> | 14. <i>C. carolinus dubius</i> (blue phase) |
| 7. <i>C. bartonii robustus</i> | 15. <i>C. limosus</i> |
| 1. <i>C. bartonii montanus</i> | |

FIGURE 1

The material for this study was collected by the writer in connection with his work as a member of the West Virginia University Biological Expedition, consisting of students and instructors of West Virginia University carrying on field work in Bioecology.

The writer is indebted to Dr. A. M. Reese, under whose direction the study was conducted, for his invaluable assistance and guidance throughout the progress of the work. Thanks are due Dr. P. D. Strausbaugh for suggesting the problem and for many helpful suggestions and criticisms. Acknowledgment is made of the kindly assistance of Professor Weimer and the members of the West Virginia University Expedition who gave material assistance in collecting and to Dr. W. L. Schmitt for numerous identifications.

During the three months spent in the field (June, July, August, 1928) the party established successive headquarters in various regions of the State, each camp period lasting for about five days during which time field trips were made to the various points of ecological interest by means of autos. On the chart is listed the places in which collections of the various species were made, also all regions in which crayfishes have been hitherto collected in so far as these are included in the authentic records known to the author. (Figure 1).

At least eighty-five percent of the total area of the State of West Virginia consists of mountains and hills, the only broad valleys being those of the Ohio, Kanawha, Potomac and the Shenandoah rivers. Thus it is primarily a mountain state possessing wide diversity of physiographic conditions. To obtain a clear conception of the general surface features, West Virginia may be divided into three parts: (a) the Ohio Valley Section, (b) the Mountain Region, and (c) the Potomac Area. The first division includes about half of the State sloping westward from the Allegheny Mountains to the Ohio river. In all places the plateau is dissected by narrow valleys giving a great variety of habitats for animal and plant life. The altitude here ranges from 200 to 800 feet. The Allegheny region may be said to begin at the 1500 ft. elevation and includes thousands of mountain tops arranged irregularly, and deeply cleft. The highest ridge of the Alleghenies is Spruce Mountain located in Pendleton County, with an elevation of 4860 feet. The remainder of the State constitutes the Potomac system usually known as the Eastern Panhandle.

Despite the fact that there are no natural lakes in West Virginia, it is one of the best watered states on account of its never-failing springs, numerous streams, and creeks, winding their way around the mountain peaks and ridges. The entire drainage of the State with the exception of a small area in Monroe County is effected by two river systems—the Ohio and the Potomac. As will be emphasized later, these mountain streams and swiftly flowing creeks and rivers afford an excellent home for the *red crayfish*—furthermore, a study of some swampy areas lying beside the rivers revealed the presence of whole colonies of these interesting forms.

HISTORICAL STATEMENT.

In so far as the writer has been able to determine, no extensive crayfish studies have ever been undertaken in West Virginia. Consequently, the credit for the data that we have at the present time goes to men, who, while engaged in Biological Survey Work in the neighboring states of Pennsylvania, Ohio, Maryland and Kentucky, made numerous expeditions into West Virginia. Here may be mentioned such men as Ortman, Faxon, Hay, Hagen, Turner and Williamson.

Ortman, late of the Carnegie Museum, has made extensive collections in Pennsylvania, northern and eastern Ohio and northern West Virginia. The records obtained prior to 1906 are included in the monograph "The Crayfishes of Pennsylvania" (Ortman '06). These furnish some valuable information concerning the habits, distribution, and ecological preferences of many common West Virginia species. He places special emphasis on the fact that the life history and habits of different species of the genus *Cambarus* are by no means similar, the differences being accounted for primarily by the different ecological conditions under which they live. Hay ('02) tells of having found the species *C. bartonii tenebrosus* abundant in several caves in Virginia and West Virginia. In this same locality he also collected an albinistic specimen.

In July 1899, Hay collected typical examples of *Cambarus bartonii carinirostris* Hay from the Tygarts Valley River at Beverly and near Elkins. He also secured a few specimens at Albright, Preston County, and at Queens, Upshur County, in the above named river basins. Again in 1900, he collected upward of 100 specimens of a crayfish closely resembling

C. putnami Faxon in southwestern West Virginia. Both Hagen and Faxon have made numerous excursions into West Virginia and some interesting information is contained in their report.

Sparganum-Ludwigia-Cambarus putnami Associes.

Some interesting field observations were made of the species *C. putnami* Faxon at a small swampy area which lies in the valley of Pond Fork between the stream and the base of the mountain situated about two hundred and fifty yards south of Uneeda Station, West Virginia. This region is a typical river valley so characteristic of those of West Virginia and the general level of the valley floor at this point is about 700 feet. The soil is of an alluvial character with a large admixture of humus.

A plot of ground 250 yards by 50 yards which composed the major portion of the swamp was selected for study (Figure 2). Five plots chosen as representative parts were marked off, the size of each being twenty-five square meters. The number of holes in each area was counted and checked and then an attempt was made to find the actual depth of one burrow in each of the five areas. Crayfish holes were observed in large numbers all about the margin of the swamp indicating a rather numerous population of these animals. The temperature of the water in the swamp was 28 degrees Centigrade. The dominant plants of this area were those of the Burr-reed Community (*Sparganum eurycarpum*), Marsh Purslane (*Ludwigia palustris*) and Swamp Loosestrife (*Decoden verticillatus*).

In the central part of the swamp there was a small clump of black willows (*Salix nigra*), the only woody plant in the entire area. The Plant Community was further characterized by the presence of several species of sedges (*Carex vulpinoidea*, *C. crinita*, *Dulichium arundinaceum*) and two rushes (*Eleocharis tenuis* and *Juncus effusus*), commonly found growing in such habitats.

The animal life of the water consisted mainly of tadpoles, salamanders, water striders, crickets, toads, frogs, snakes, insect larvæ, and various species of entomostraca. The following is a list of predominant forms observed in this associes:

SCIENTIFIC NAME	COMMON NAME
<i>Natrix sipedon</i>	Water snake.
<i>Hyla crucifer</i>	Spring peeper.
<i>Triturus viridescens</i>	Yellow-backed Salamander.
<i>Diadophis punctatus</i>	Ring-necked Snake.
<i>Heterodon contortrix</i>	Hog-nosed snake.
<i>Rana clamitans</i>	Green frog.
<i>Rana catesbeiana</i>	Bull frog.
<i>Bufo americanus</i>	Common toad.

The accompanying diagram (Figure 2) will indicate the relative location of areas where following records were made.

AREA No. I.

Hole No. 1.

Depth of water table below surface.....	33 cm.
Depth at which crayfish was found.....	86 cm.
Bottom not reached.	

Hole No. 2.

Depth of water table below surface.....	27 cm.
Depth at which crayfish was found.....	72 cm.
Bottom not reached.	
Number of crayfish holes—21.	

AREA No. II.

Hole No. 1.

Depth of water table below surface.....	31 cm.
Depth at which crayfish was found.....	48 cm.
Number of crayfish holes in area—37.	

AREA No. III.

Hole No. 1.

Depth of water table below surface.....	37 cm.
Crayfish not found.	
Depth of hole.....	145.5 cm.
Number of crayfish holes in area—25.	

AREA No. IV.

Hole No. 1.

Depth of water table below surface.....	42 cm.
Number of crayfish holes in area—11.	

AREA No. V.

Not tested for depth of water table.
Number of crayfish holes in area—21.

One hole in another part of the field was found to be over six feet in depth. The average number of holes in the five areas examined is 23, and on this basis the total number in the swamp is approximately 9615.

All the holes that were examined closely went straight down from four to eight inches, then they made an abrupt turn and continued downward to the water table. Crayfishes were seen lying near the edge of their burrow and it was found that upon the slightest stimulation they immediately crawled

over the edge and dropped into the holes. Thus it would seem that the perpendicular nature of the upper part of the hole is of advantage in that it affords an easy avenue of escape when attacked by enemies. It was not always possible to determine the full depth of the burrow because of the constant inflow of water. During the day crayfishes were usually found deep in their burrows.

Ortman ('06) distinguishes between three main types of ecological conditions among crayfishes. First, there are those species which generally live in the larger rivers; second, those preferring the ground water where it is not far from the surface and appears in the shape of springs and swamps; third, those that prefer intermediate conditions and select smaller streams

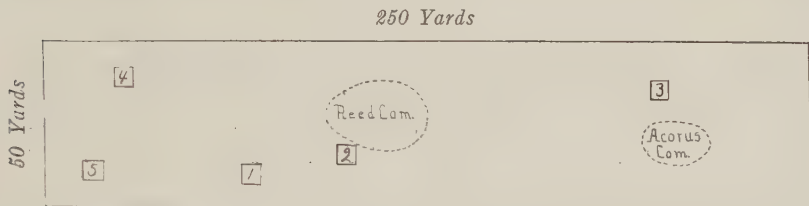


FIGURE 2

A drawing to show distribution of plots in the area in which studies of *Cambarus putnami* were made

for their homes. He aptly calls these the "river species," "mountain stream species," and the "burrowing species." Almost all the crayfishes of West Virginia will, in my estimation, fall in one of these categories, and so they will be used in the discussion that follows.

The data listed above would seem to point quite conclusively to the fact that *C. putnami* Faxon is a burrowing species. In the daytime, without exception, they were found in the ground water of their burrows. A few chimneys were observed at the entrance of some of the holes. Since the way of carrying the mud out of the holes seems to be identical in all burrowing species the following quotation from Ortman ('06) is of interest. "In digging, the chelæ of the first pereopods are used. The fingers are slightly spread out so they are about parallel, thus acting as forks for digging. They are pushed vertically down into the mud on both sides at the same time and a lump of mud is thus loosened and lifted toward the ventral surface of the body. In lifting, the chelipeds are bent

toward the body (the region of the mouth), and finally the ball of mud is appressed to the anterior part of the body and held in position by the chelæ. Very likely, also, the third maxillipeds take hold of it but it was impossible to ascertain this. In this position, as Goodman expresses it, carrying an armful of dirt, (or rather two armsful), the crayfish walks slowly and deliberately to the mouth of the hole. I have repeatedly observed this coming out in nature. It advances to the top of the chimney and deposits the mud pellet upon the rim. Finally pushing it into proper position with the upper (outer) surface of the claws. This latter act apparently was seen by Mr. J. DeB. Abbot; but according to my experience the mud is not brought up upon the back of the claw but held as described above between the folded claws and the anterior part of the body."

In this particular region no chimney openings were found closed. In other regions of the state, such as at Welch, burrows of the species *C. bartonii robustus* Girard and *C. carolinus dubius* Faxon were found closed. The height of the chimneys averaged about nine inches.

How important a factor is the chimney of the crayfish habitat? Tarr ('84) states that he does not regard the chimney as a necessary part of the nest but simply the result of digging. In the estimation of Dr. A. E. Ortman, the construction of the hole is the chief aim for which the crayfish works. It not only affords protection for the crayfish and its young from such enemies as snakes, but protects the hole from the disturbing influences of rain and frost. Observations would indicate that females with eggs or young are usually found in closed holes. Various environmental factors such as slope of land and character of soil influence the shape of the chimneys. Young specimens usually build more regular chimneys than old ones, due probably to the fact that old specimens live in burrows that are practically completed, with the result that the mud that is removed is softer and makes rather irregular chimneys. Abbot ('84) is of the opinion that closed chimneys are caused by the falling in of the rim. On several occasions I have found burrows that were closed by a "stopper" extending down at least 18 mm. below the surface of the ground, and the firmness of the soil constituting the stopper was of such a nature that it could hardly be explained as an accidental falling in of the rim.

The above listed animals and plants present in the swamp are quite characteristic of the forms usually found in association with crayfish aggregations.

FOOD.

Observation of specimens in captivity as well as those in their natural environment leads one to believe that they are generally omnivorous. They will eagerly devour almost any organic substance whether it be animal or vegetable. In captivity, I have known one instance in which *C. carolinus dubius* Faxon devoured a blue crayfish *C. carolinus dubius* Faxon (blue phase) (Newcombe '29) of almost equal size. On one occasion I observed a small form feeding on a dead fish. Some species are commonly known to devour their own cast off shell after moulting.

During the day crayfishes are usually found at rest, seeking shelter under a submerged log or rock crevice, while at night they are very active since it is at this time that they go in search of food. Quoting from Pearse ('10) "their activities are strictly utilitarian, being confined to such necessary movements as are concerned in mating, seeking and capturing food, and searching for environmental conditions."

DISTRIBUTION OF WEST VIRGINIA SPECIES.

The records of the localities and dates at which the different species of crayfishes from West Virginia have been reported, have been assembled and represented in the following tables:

TABLE I.

SPECIES	LOCALITY COUNTY	PLACE	DATE	OBSERVER
<i>C. putnami</i>	McDowell	Barrenche creek, near Perryville	Summer of 1900	Hay
	Mingo	Horsefen Creek	"	"
	McDowell	War Creek	"	"
	Mineral	Patterson's Creek, near Burlington	Summer of 1928	Newcombe
	Boone	Near Uneeda	"	"
<i>C. obscurus</i>	Upshur	Queens	?	?
	"	Cheat River	?	?
	"	Ice's Ferry	?	?
	"	Sand Run	?	?
	"	Childer's Run	?	?
	"	Nubies' Run, near Buckhannon	?	?

TABLE I—Continued.

SPECIES	LOCALITY COUNTY	PLACE	DATE	OBSERVER
<i>C. obscurus</i>	Lewis	Weston	?	?
	"	Hacker's Creek, near Jane Lew	?	?
	Harrison	Ten Mile Creek at Lumberport	?	?
	Hancock	Harmon's Creek, (Holiday's Cove)	?	Ortman
	Randolph	Cassidy	?	"
	Brooke	Harmon's Creek, (Colliers)	?	"
	Monongalia	Decker's Creek above Morgantown	?	"
	Ohio	Wheeling Creek (Elm Grove)	?	"
	Marshall	Wheeling Creek (Union Township)	?	"
	"	Grove Creek (Cameron)	?	"
	"	Pennsylvania Fork of Fish Creek, Nuss.	?	"
<i>C. propinquus sanbornii</i>	Wetzel	Fishing Creek, (New Martinsville)	?	"
	Pleasants	Middle Island Creek	?	?
	Wetzel	New Martinsville Fishing Creek	?	?
	Mineral	Patterson's Creek near Burlington	August, 1928	Newcombe
<i>C. bartonii</i>	Monongalia	Near Morgantown	April, 1929	"
	Marshall	Fish Creek (Panhandle)	?	?
<i>C. bartonii</i>	Morgan	Cherry Run	?	?
	Tucker	Blackwater Run, Davis	?	?
	Grant	Patterson Creek, South Branch of Potomac	?	Faxon
	Monongalia	Cheat River	?	Smith
	"	Morgantown	?	?
	Pleasants	St. Mary's	?	?
	Wetzel	New Martinsville	?	?
	Marshall	Cameron	?	?
	Ohio	Elm Grove	?	?
	Brooke	Colliers	?	?
	Hancock	Holiday's Cove	?	?
	"	Congo	?	?
	Pendleton	West Branch of Potomac River	?	?
	Mercer	Rich Creek	?	?
	"	Spanishburg	?	?
	Upshur	Nubies' Run, near Buckhannon	?	?
	Randolph	Glade Creek	?	Faxon
	Grant	North Hill Creek, near Petersburg	June, 1928	Newcombe
	Monroe	Wolf's Creek, near Alderson	"	"
	Boone	Jarrel's Run	"	"

TABLE I—Continued.

SPECIES	LOCALITY COUNTY	PLACE	DATE	OBSERVER
<i>C. bartonii</i>	Ritchie	Petroleum	?	Faxon
	Pocahontas	Cranberry (7 miles from Hillsboro)	July, 1928	Newcombe
	"	Lion Lithia Springs, (near Dunmore)	August, 1928	"
<i>C. bartonii robustus</i>	MacDowell	Brook's Creek	July, 1928	Newcombe
	Greenbriar	Greenbriar River (near White Sulphur Spgs.)	"	"
	Greenbriar	West Fork of Greenbriar River	?	?
	Mercer	Crane Creek	?	?
<i>C. bartonii montanus</i>	Greenbriar	Greenbriar River,	?	?
	"	Kanawha River	?	?
	Mingo	Horsepen Creek	?	Faxon
	Summers	Madam Creek, (near Hinton)	?	"
	Mercer	Bergens Springs, (near Hinton)	?	"
	"	Delasmeet Creek	?	"
	"	Kegley	?	"
	"	Bluestone River	?	"
	"	Abb's Valley	?	"
	"	East River	?	"
	"	Rich Creek	?	"
	"	Spanishburg	?	"
	Greenbriar	Barrenche	?	"
	"	War Creek	?	"
	Wyoming	Guyandotte River (Baileysville)	?	"
<i>C. limosus</i>	Morgan	Potomac	?	Ortman
	"	Cherry Run	?	"
<i>C. carolinus monongalensis</i>	Ohio	Bethany	April, 1929	Weimer
	Hancock	Congo	?	Ortman
	Westmoreland	Bethany	?	"
	Hancock	Holidays Cove	?	"
	Brooke	Colliers	?	"
	Ohio	Elm Grove	?	"
	Marshall	Cameron	?	"
	"	Nuss	?	"
	Monongalia	Morgantown	?	"
<i>C. carolinus carolinus</i>	Preston	Terra Alta	?	Faxon
	"	Reedsville	?	"
	Tucker	Parsons	?	"
	Mineral	Schell	?	"
	Southwestern	West Virginia	?	Hay

TABLE I—Continued.

SPECIES	LOCALITY COUNTY	PLACE	DATE	OBSERVER
<i>C. bartonii carinirostris.</i>	Randolph	Candee Creek Osceola	July, 1899	Hay
	Preston	Albright	"	"
	Upshur	Queens'	?	"
	Pocahontas	West Fork of Green- briar River (near Dunmore)	?	"
	Monroe	Laurel Creek (near Greenville)	?	"
<i>C. bartonii veteranus....</i>	Wyoming	Indian Creek, (near Baileysville)	?	?
	Mercer	Crane Creek	?	?
	Kanawha	Elk River, Cogars' Mills	?	?
<i>C. diogenes.....</i>	Hancock	Congo	?	?
	Brooke	Colliers	?	?
	Wetzel	New Martinsville	?	?
Monongalia		Cobun's Run, (Near Morgantown)	April, 1929	Newcombe
	"	Childer's Run, (Near Buchanon)	?	Faxon
<i>C. bartonii longulus.....</i>	Pocahontas	West Fork of Green- briar River, (Near Durbin)	?	?
	Mercer	Bluestone River	?	?
	"	Abb's Run	?	?
<i>C. carolinus dubius</i>	Preston			
	Mineral			
	Tucker			
	Boone	Uneda	June, 1929	Newcombe
	Mingo	Brooks Creek, (Near Welch)	July, 1929	"
<i>C. carolinus dubius..... (blue phase)</i>	Pocahontas	Cool Run, (near Cass)	August, 1929	Newcombe
	Pendleton	Spruce Mt. (Spruce Knob)	"	"
	Pocahontas	Bald Knob	"	"

In considering the distribution of individuals and species with reference to local factors such as temperature, purity and rapidity of stream, direct and detailed observations are very scarce, while conclusions as to distribution in the broader

sense, the range of species, groups and the genus itself are limited on account of insufficient investigation.

On the subject of the ecological phases of the distribution of crayfishes very little has appeared. Faxon ('85) records the occurrence of the same species in the headwaters of streams on the opposite sides of a water shed, as has been observed in fishes and gives as examples *C. extraneus* and *C. spinosus* in the upper waters of the Santee, Alabama and Tennessee rivers, and also states that the forms of the upper and lower part of a river may be different. To illustrate this point he gives *C. bartonii* and *C. latimanus*, *C. acuminatus* and *C. spinosus* in the upper part of the Santee River, while in the lower portion of the same basin live *C. blandingii acutus* and *C. troglodytes*. Only a relatively small number of observations have been recorded concerning the appearance of different species in different types of localities.

Crayfishes are found in a great variety of habitats from burrows in a prairie which is dry for a large part of the year, stagnant ponds, roadside ditches and salt marshes to the pure cold water of mountain streams and springs. Just as fish are known to be typical of each class of habitat, so, in all probability, are crayfishes, although, perhaps, to a less extent. It must be noted here that there are, in the limited literature on the habits and distribution of the different forms, numerous accounts of instances wherein the same species has been observed in entirely different environments. The author collected specimens of *C. carolinus dubius* Faxon at Brooks Creek, a cool swiftly flowing mountain stream, situated about two miles from Welch, W. Va., and also from a filthy stagnant pool near Morgantown. *C. putnami* Faxon, as will be shown later, was collected from two distinctly different types of habitat, one a swampy area at Uneeda, W. Va., the other a swiftly flowing stream, Patterson's Creek, two miles north of Burlington, W. Va. The species given are sufficient to illustrate the point in question.

It is possible to assign certain species quite definitely to some type of habitat. The burrowing species obviously have a great advantage over the other forms in the matter of distribution as they are able to occupy territory which is not available for others, except at certain seasons. *C. diogenes* Girard is the most widely distributed species of the genus, occurring in Boulder Co., Colorado at the foot of the Rocky Mountains

and in southeastern Wyoming, in Minnesota, Wisconsin, and Michigan; in New Jersey, Maryland, West Virginia, Virginia, North and South Carolina; and in Mississippi and southern Louisiana. *C. carolinus* long known from only the Appalachian region of Virginia is now known to occur in northeastern Indian Territory, Western Pennsylvania and West Virginia.

Among the species that appear to be confined to mountain streams may be mentioned *C. bartonii* Fabricius (common in West Virginia), *C. longulus* (also found in West Virginia), *C. extraneus*, *C. spinosus*, *C. acuminatus* and *C. forceps*. It is interesting to note the range in altitude as well as in longitude and latitude. *C. diogenes* Girard has been reported from Boulder County, Colorado and also southern Louisiana. I have observed a blue phase of *C. carolinus dubius* Faxon at an elevation of approximately 4500 feet at Spruce Knob, West Virginia, and also 2400 feet near Cass, West Virginia.

DISCUSSION OF SPECIES.

It is not the intention of the writer to include in this paper a thorough taxonomic description of the various species of West Virginia crayfishes. Considerable attention will be paid, however, to *C. carolinus dubius* Faxon and *C. carolinus monongalensis* Ortman on account of their resemblance to a new color phase of *C. carolinus dubius* Faxon collected by the author at Cass, West Virginia.

Cambarus carolinus monongalensis Ortman.

LOCALITY—Hancock County, Congo, Hollidays Cove;—Brooke County, Colliers;—Ohio County, Elm Grove;—Marshall County, Cameron, Nuss;—Monongalia County, Morgantown.

Cambarus carolinus dubius Faxon.

LOCALITY—Mineral County, Preston County, and Tucker County.

NEW LOCALITY—*Monongahela County, Westover, near Morgantown; MacDowell County, Brook's Creek, near Welch, West Virginia (U. S. N. M. No. 103761).

Cambarus carolinus carolinus Erichson.

LOCALITY—Preston County, Reedsville;—Tucker County, Parsons;—Mineral County, Schell;—Southwestern West Virginia (Hay);—Preston County, Terra Alta (Faxon).

*Under this heading are listed regions in which the writer made collections.

DISCUSSION OF TAXONOMY.

These three species exhibit considerable similarity and there does not seem to be a generally accepted basis for differentiating them. For this reason, the writer has endeavored to follow the classification of Faxon and has considered the three groups together. *Cambarus carolinus monongalensis* Ortman, commonly known as the blue or Monongahela crayfish, was first collected at Pittsburgh, Pennsylvania in 1898, by E. B. Williamson. Compared with the type of *C. dubius* these specimens showed a narrower rostrum with less pronounced angles at the base of the acumen, the outer border of the hand was evenly rounded not ridged and destitute of the serrature seen in *C. dubius* where this feature results from the regular row of transversely elongated marginal punctations giving to the margins a milled appearance; further, the carpus of the Pittsburgh form was armed with several accessory spines and tubercles beside the prominent internal median spine which is all the armature of the carpus in *C. dubius*.

E. A. Ortman, '06, showed that the blue crayfish and *C. dubius* both live in western Pennsylvania, that they occupy different areas separated by the Chestnut Ridge, a range of hills on the west of the Allegheny Mountains, *C. monongalensis* Ortman being found on the hills lying on the west of the range, while *C. dubius* lives in the mountain region to the east of Chestnut Ridge between it and the principle range of the Allegheny Mountains. In this same paper, Ortman brought out clearly the color difference between the two forms, the dominant color of *C. dubius* being red, that of *C. monogalensis*, blue. The range of the latter form appears to be rather narrow, being restricted as far as is shown by Ortman, to Westmoreland, Allegheny, Beaver, Washington, Fayette, and Green Counties, Pennsylvania, and Hancock, Brooke, Ohio, Marshall, Monogalia counties of West Virginia at altitude ranging from 800 to 1200 feet above sea level.

Ortman compared his specimens of *C. monogalensis* with the northern race of *C. carolinus*, i.e., *C. dubius*, and came to the conclusion that they represented a distinct species. From the above, however, it is seen that three of the characters which Ortman thought more peculiar to *C. monogalensis* are also present in the southern typical form of *C. carolinus*, viz., the narrower rostrum, the non-serrated margin of the hand,

and the presence of more than one spine on the inner side of the carpus. There are thus left but two features to separate *C. monongalensis* from *C. carolinus*, namely, the uniserial disposition of the spines on the lower face of the merus of the cheliped and the color. Taking a broader conception of the geographical variations of these interesting forms Faxon considers *C. carolinus* Erichson, *C. dubius* Faxon, and *C. monongalensis* Ortman as three geographical races or sub-species of one species. For distinguishing these three sub-species he gives the following key:

- Lower face of merus with only one row of spines developed. Color, blue.....*C. carolinus monongalensis* (Ortman)
- Lower face of merus with two rows of spines developed. Color, red.....
- | | |
|--|--|
| Margins of rostrum distinctly convergent; outer margin of band rounded, not serrated; more than one spine on inner margin of the hand..... | <i>C. carolinus carolinus</i> (Erich.) |
| Rostrum broader with nearly parallel margins; outer margin of hand subserrate; only one spine on inner margin of the hand, | <i>C. carolinus dubius</i> Faxon |

The form spread over the southwestern part of West Virginia, as has been pointed out, is more or less intermediate between *carolinus* and *dubius*, while the pure *C. carolinus dubius* has been reported from Preston, Tucker, and Mineral Counties, West Virginia.

Cambarus carolinus dubius Faxon (Blue Phase).

The writer collected two young blue specimens at Cass, West Virginia and assumed them to be *C. carolinus monongalensis* Ortman. On identification, Dr. W. L. Schmidt found that the distinguishing characters absolutely preclude this. He found them to possess the lateral compression of the carapace and the areola wider than would be expected for the young of *dubius*, yet too narrow for the young of *C. bartonii*. He writes as follows: "On described characters and comparing your small specimens with my much larger *monongalensis* they cannot be that species. This rather upsets the exclusiveness of color of the latter, for your evidence shows *dubius* to have a blue phase, at least in the case of some—your two young."? (Specimens).

At a later date, I sent him several blue specimens that were collected for me by Prof. Weimer at Bethany, Ohio County, West Virginia. These he found to be Ortman's sub-species *monongalensis* possessing the single row of spines on the wider side of the merus of the chelipeds. He writes as follows: "There is no question about these specimens, but I was concerned enough to go back and look at the *dubius* that we had retained from your former sending and that, to the best of my knowledge, is a good *dubius* because there are two rows of spines beneath."

NEW LOCALITY—Pocahontas County, Cool Run, Cass; Bald Knob, near Cass;—Pendleton County, Spruce Knob (probably).

HABITAT—Cool Run is a cold mountain stream, swiftly flowing and the crayfishes were not obtained from the stream but from their hiding places in the side of the bank, a few feet above the water. It was a damp, rocky area and they seemed to be concealed under the rocks. No characteristic burrows were observed in this area. From the stream were collected several specimens of *C. bartonii* Fabricius. A blue specimen was observed at Spruce Knob in Pendleton County, elevation about 4500 feet, and it is quite possible that it was the same blue phase of *C. carolinus dubius* Faxon since Ortman's *monongalensis* has not to my knowledge been reported as far south. It is worth noting that the range of the latter is from 800 to 1200 feet while that of the former is 2400 feet to 4500 feet approximately. Although all the areas where the blue phase of *C. carolinus dubius* were found were cool, damp regions, there is no evidence to indicate that they inhabit streams. This discovery of a new color phase in the genus *Cambarus* which encroaches on the exclusiveness of *C. carolinus monongalensis* Ortman leads us to ask, "What are the factors that control color in crayfishes?" Are we to look to genetics for an explanation or is it to be accounted for on a purely ecological basis?

C. carolinus dubius Faxon.

As far as is known the red crayfish *C. carolinus dubius* Faxon occupies a very small area of the State. The writer collected specimens from Brook's Creek, situated about two miles from Welch, West Virginia, and also at Westover, one mile north of Morgantown. The former was a shallow rapidly

flowing stream, water being noticeably cold and very clear, while the latter was a very stagnant shallow pool. In no case did the writer find the blue phase of this species in the water of the stream. They were obtained by digging in the bank of soil, probably three feet above the water. Not enough habitats of this group were studied to justify any opinion concerning the ecological preference of this type. Ortman, in comparing *C. carolinus* and *monongalensis* says that although they are very closely allied, nevertheless the distinguishing characters are constant; identical in their ecological habits they are separated topographically. As to the actual causes of the differences of the specific characters, or in other words what external influences are responsible for then, little is known at the present time. It is certain, however, that these two species illustrate the rule that closely allied species occupy neighboring areas and they illustrate the fact that specific differentiation is due to isolation which is topographical in this case.

Cambarus propinquus Girard.

LOCALITY—This species has a limited range in West Virginia, having been found only in the northern tip of the state.

C. obscurus Hagen.

LOCALITY—Upshur County, Cheat River, Ices Ferry, Sand River, Queens, Childers River, Trubies Run (near Buckhannon);—Lewis County, Weston, Backer's Creek (near Jane Lew);—Harrison County, Ten Mile Creek (at Lumberport);—Randolph County, Cassidy;—Monongalia County, Decker's Creek;—Marshall County, New Martinsville.

Cambarus propinquus sanbornii Faxon.

LOCALITY—Kanawha County, Horse Creek; Wetzel County, Fishing Creek, New Martinsville; Pleasants County, Middle Island Creek, St. Marys.

NEW LOCALITY—Mineral County, Patterson's Creek, two miles north of Burlington; Lewis County, Bushy Fork, seven miles northwest of Weston. (U.S.N.M. No. 103,761).

These three species (*C. obscurus*, *C. propinquus*, *C. propinquus sanbornii*) resemble each other very closely. They live under similar ecological conditions and their ranges form a unit so it is evident that they are closely allied genetically. Within the established range of *C. obscurus* from Fish Creek in the southern part of the Panhandle of West Virginia to the upper

Allegheny and the Genessee Rivers in McKean and Potter Counties and from Cheat River at the West Virginia state line to the upper Shenago River in Crawford County, Pennsylvania, this species is remarkably uniform in taxonomic characters (Ortman '06). As is pointed out above, *C. propinquus sanbornii* and *C. propinquus* G. have a very narrow distribution in West Virginia.

Cambarus bartonii Fabricius.

LOCALITY—Morgan County, Cherry Run; Tucker County, Black Water River, Davis, Shavirs Fork, Parsons; Monongalia County, Cheat River (H. H. Smith, Collector) Morgantown; Pleasants County, St. Marys; Wetzel County, New Martinsville; Marshall County, Cameron; Ohio County, Elm Grove; Brooke County, Colliers; Hancock County, Holiday's Cove, Congo; Pendleton County, West Branch of Potomac River, five miles west of Circlesville; Mercer County, Rich Creek, Spanishburg; Upshur County, Trubies Run, seven miles above Buckhannon.

NEW LOCALITY—Boone County, Jarrels Run (near Uneeda); Monroe County, Wolfs' Creek (near Alderson); Grant County, North Mill Creek (situated about five miles from Petersburg); Pocahontas County, Cranberry River (seven miles from Hillsboro), Lion Lethia Springs (one mile from Dunmore); Mineral County, Patterson's Creek near Greenland Gap.

HABITAT—*Cambarus bartonii* Fabricius is essentially a "mountain stream species." It prefers irregular cool well aerated mountain streams and also frequents springs but is seldom if ever found in rivers. During the day they are to be found along the banks hiding under rocks while at night they go in search of food. Sometimes they scoop out a hollow under a stone and establish their residence. Ortman ('06) reports instances of finding rather complex burrows of this species going down to a depth of a foot or more. These burrows extend along the banks of the streams usually not more than a few feet from the water's edge. *C. bartonii* Fabricius is not an habitual chimney builder and is more commonly found under the sheltered parts of rocks.

Cambarus bartonii robustus Girard.

LOCALITY—In the U. S. N. M., there are many specimens from the West Fork of the Greenbrier River, West Virginia and from Crane Creek, West Virginia, which are nearly typical examples of *Cambarus bartonii robustus* Girard according to Faxon ('14).

NEW LOCALITY—MacDowell County, Brook's Creek near Welch; Greenbrier County, the Greenbrier River near White Sulphur Springs, West Virginia.

HABITAT—It is a common brook species found in habitats similar to *Cambarus bartonii* Fabricius.

Cambarus bartonii montanus Girard.

LOCALITY—Mingo County, Horsepen Creek; Summers County, Madam Creek, tributary of New River, opposite Hinton; Mercer County, Bergen's Springs, twelve miles from Hinton, Delasmeet Creek, Kegley, Mercer County, Bluestone River, just above its mouth. Mouth of Delasmeet Creek, Bluestone River, Abb's Valley, East River, Rich Creek, Spanishburg; MacDowell County, Barrenche Creek, Perryville, War Creek; Wyoming County, Guyandotte River, Baileysville, West Virginia.

Cambarus bartonii carinirostris Hay.

LOCALITY—This is a slightly differentiated form of *C. bartonii* found chiefly in the mountain streams of Randolph County, West Virginia the Cheat and Tygarts Valley Rivers and their tributaries. Outside of Randolph County, Hay secured a few specimens at Albright, Preston County, and at Queen's, Upshur County, in the above named river basins. According to Faxon it is also probably to be found in the upper waters of the Kanawha River basin further to the south since there are a few specimens in the U. S. N. M., from the West Fork of the Greenbriar River near Durbin, Pocahontas County, and from Laurel Creek, in second Water Cave near Greenville, Monroe County, that are pretty characteristic examples of this race.

Cambarus bartonii longulus Girard.

LOCALITY—Pocahontas County, West Fork of the Greenbriar River near Durbin, Bluestone River and Abb's Valley.

Cambarus bartonii veteranus Faxon.

LOCALITY—Wyoming County, Indian Creek, Baileysville; Mercer County, Crane Creek; Kanawha County, Elk River, Cogar's Mills, West Virginia.

HABITAT—There have been few observations made on the forms of *C. bartonii longulus*, *C. bartonii veteranus*, and *C. bartonii carinirostris* and *C. bartonii longirostris*. It is quite safe to assume, however, that with regard to ecological preference they bear marked similarity to *C. bartonii* previously described.

Cambarus diogenes Girard.

LOCALITY—Hancock County, Congo; Brooke County, Collier; Wetzel County, New Martinsville.

NEW LOCALITY—The writer collected several specimens from Cobun's Run Creek near Morgantown questionably determined as this species by Dr. W. L. Schmidt of the Smithsonian Institution. He has informed me that there are in the Nat. Mus. at Washington, ten juveniles also questionably determined as this species over the name of Walter Faxon. These came from Childer's Run, three miles northeast

from Buckhannon, West Virginia. Ortman ('06) after a thorough search concluded that this form is positively absent in Preston, Tucker, and Mineral Counties, West Virginia.

HABITAT—*Cambarus diogenes* has the widest range of any species of *Cambarus*. It belongs to the burrowing group and its holes and chimneys are to be found along river banks as well as in meadows and marshes often occurring at some distance from open water. As a natural consequence of the habit of preferring swamps to springs, *C. diogenes* is generally found at a lower elevation than *C. carolinus* and *monongalensis* where it comes into contact with them. I have collected them from stagnant sewage offering a minimum of conditions favorable to respiration and other physiological life processes. According to Ortman ('06) in the case of *C. diogenes*, it is chiefly in mid-summer that the young begin to build their own holes. However, in other species this may take place at any time, from spring to fall and consequently the new and often very irregular chimneys of small specimens may be seen at any time during the warm season. Some valuable studies have been made on the burrows of this species by Faxon ('85), Girard ('52), Tarr ('84), Holder ('86) and Schiufeldt ('96), and others. Quoting from Hay ('96), "The subterranean tunnels may sometimes be found to extend for several feet and, as the animal frequently excavates them at some distance from the water, they must reach a depth great enough to supply moisture sufficient for the need of the animal. During the dry months of the summer, however, they seem to live in the end of their burrows in a sort of stupor. I have often seen them fall from the end of an excavation, apparently lifeless, capable of moving when put in water.

In the early spring, when they go forth to breed, is the only season when they are a noticeable number of our fresh water fauna. They move about chiefly at night though I have frequently taken numbers of them from ditches and small streams on bright sunny days."

Cambarus (Faxonius) limosus Rafinesque.

LOCALITY—The distribution of this species in West Virginia is very limited being reported by Ortman from the Potomac River and Cherry Run, Morgan County.

HABITAT—*C. limosus* is primarily a river species and belongs to the rivers, ponds and canals of the lowlands of the Atlantic Coastal Plain and the Piedmont region.

Cambarus putnami Faxon.

LOCALITY—MacDowell County, Barrenche Creek near Perryville; Mingo County, Horsepen Creek; MacDowell County, War Creek. Specimens closely resembling *C. putnami* were collected in 1900 by Hay.

NEW LOCALITY—Mineral County, Patterson's Creek, two miles north of Burlington; Boone County, near Uneeda, five miles from Madison, West Virginia.

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PRINCIPLES OF PLANT TAXONOMY, VIII*.

JOHN H. SCHAFFNER.

In the seventh paper of this series, a phylogenetic synopsis was presented of the orders of the META-THALLOPHYTA. A similar synopsis is now given of the orders of THALLOPHYTA. The two diagramatic "trees" of relationships may be put together and thus a crude picture of the phyletic relationships of the entire plant kingdom will be represented from the lowest stage to the highest with all the multitudinous ramifications out to the orders.

The Archemycetæ as described in the Ohio Jour. of Sci. 27: 250, 1927, should be shifted in the list to immediately follow the Myxomycetæ and re-defined as being mostly sexual; since it now appears that most of them have some sort of a conjugation process.

There are many problems of a fundamental nature in the thallophytes which cannot be solved at present, because of a lack of knowledge of life histories. This is especially true of the lower green algæ, the lower brown algæ, the archemycetes, and the ascomycetes. So long as the genera and families are not properly segregated, it will be impossible to deal conclusively with the larger groups. This fact should not deter us, however, from attempting to make a correct phyletic taxonomy. Every careful attempt will bring the true taxonomic view nearer. The older morphological speculations, which did not distinguish progressive series from digressive movements or segregations, could not construct a true taxonomic system because they made no definite attempt to judge structures and individuals on a phyletic basis, but merely compared similarities and differences, and frequently deduced phylogenetic sequences which required a series of re-creations, if the one form was actually to be evolved from the other. Thus many of the taxonomic sequences which are at present widely accepted are a contradiction to any evolutionary theory of origins whatever unless one is willing to subscribe to the

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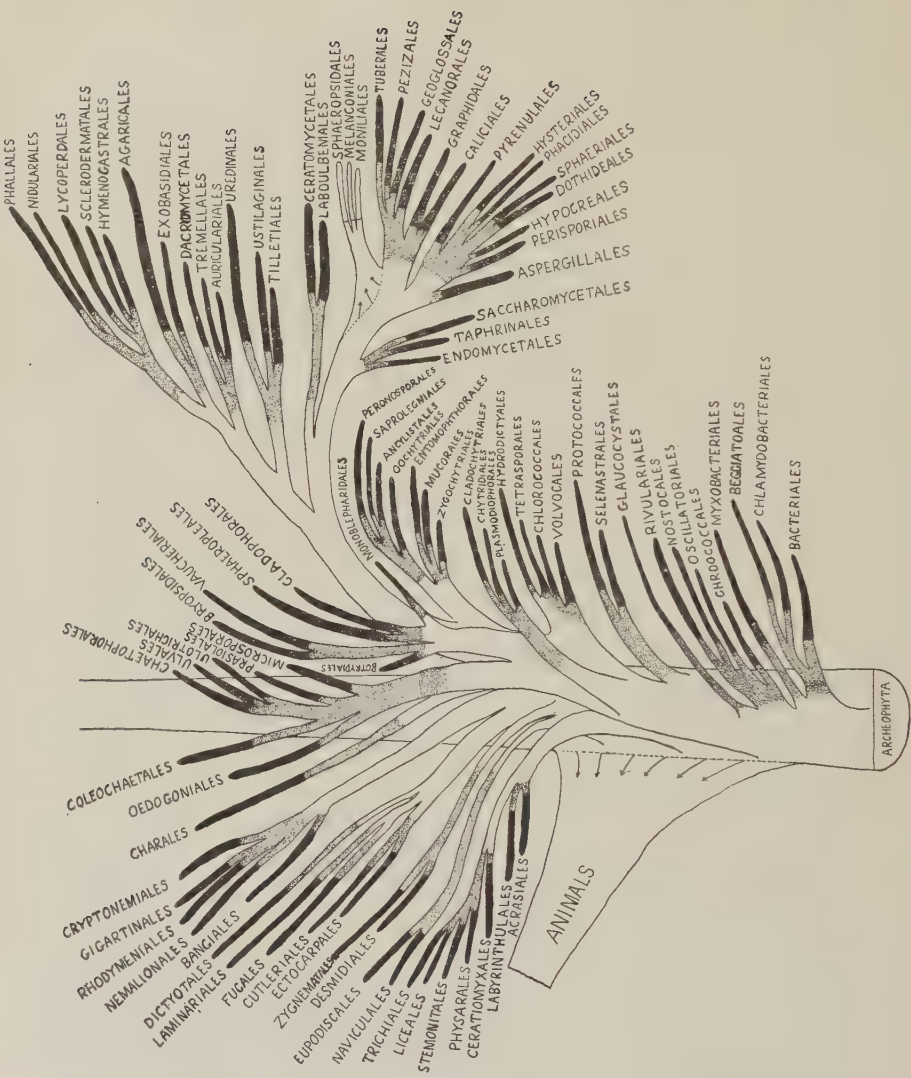


Fig. 1. Diagram of the phyletic relationships of the Orders of Thallophyta.

fantastic notion of frequent and violent re-creations in the phylogenetic series.

SYNOPSIS OF THE CLASSES AND ORDERS OF SCHIZOPHYTA.

- I. Cells without chlorophyll, sometimes with bacterio-purpurin; holophytic, saprophytic, or parasitic fungi.
 - A. Cells not imbedded in a pseudo-plasmodium; life cycle not with two distinct, vegetative and fruiting periods; not forming a myxomycete-like fructification, altho the cells may be in gelatinous masses.

SCHIZOMYCETÆ. Bacteria.

 1. Cells without bacterio-purpurin and without sulfur granules; if in chains or filaments, then without a sheath. *Bacteriales. Bacteria.*
 2. Cells with bacterio-purpurin, with sulfur granules or with both; unicellular or filamentous; or filamentous bacteria with definite sheaths.
 - a. Cells in filaments covered with a more or less definite sheath, without sulfur granules and without bacterio-purpurin.

Chlamydo-bacteriales.
 - b. Cells separate or if in filaments not covered with a sheath; with sulfur grains, or with bacterio-purpurin, or with both.

Beggiatoales.
 - B. Cells in a pseudo-plasmodium; life cycle with two distinct periods, a vegetative period and a fructification period when a myxonycete-like fruiting body is developed with or without a stalk. MYXOSCHIZOMYCETÆ.
One order, *Myxobacteriales.* Slime Bacteria.
- II. Cells containing chlorophyll and phycocyanin; algæ usually of a blue-green or brownish color.
 - A. Without a definite nuclear membrane and with a low type of chromatophore. CYANOPHYCEÆ. Blue-green Algæ.
 1. Not filamentous; cells free or in masses or plates (superficial aggregates); or the cell individuals with definite base and apex, in fruiting sometimes forming a row of cells.....*Chroococcales.*
 2. Cells arranged in definite filaments.
 - a. Filaments without hair-like tips, but sometimes narrowed at the ends.
 - (a) Without heterocysts; free filaments commonly massed into flat layers, sometimes several filaments enclosed in one common sheath.....*Oscillatoriales.*
 - (b) With intercalary heterocysts.....*Nostocales.*
 - b. Filaments with hair-like tips at one or both ends, without or with basal heterocysts.....*Rivulariales.*
 - B. With nuclear membrane and highly differentiated chromatophores, unicellular or in colonies. GLAUCOCYSTÆ. Higher Blue-green Algæ.
One order, *Glaucocystales.*

SYNOPSIS OF THE CLASSES AND ORDERS OF MYXOPHYTA.

- I. Without zoospores; the cells not fusing into a typical plasmodium, but simply aggregated; spore mass without a covering.

ACRASIEÆ. Primitive Slime Molds.

 - A. Cells ameboid, forming a typical aggregation plasmodium....*Acrasiales.*
 - B. Cells not ameboid, but with rather rigid form, aggregating into a net-like plasmodium.....*Labyrinthulales.*
- II. With zoospores containing a single flagellum; plasmodium of completely fused cells. MYXOMYCETÆ. Slime Molds.
 - A. Spores developed superficially upon erect branching sporophores, no sporangia being produced. Subclass CERATIOMYXÆÆ.
One order, *Ceratiomyxales.*

- B. Spores developed within a sporangium-like body with a wall, the sporangia distinct or united into an æthelium. Subclass. MYXOGASTERÆ.
 - 1. Spores dark, brown, black, or violet; capillitium present.
 - a. Fructification with lime, capillitium present. *Physarales*.
 - b. Fructification without lime; capillitium solid. *Stemonitales*.
 - 2. Spores generally yellowish in color, never black; capillitium present or absent; lime absent.
 - a. Capillitium absent; the frayed walls of the sporangium may sometimes resemble a capillitium. *Liceales*.
 - b. Capillitium present, tubular or solid. *Trichiales*.

SYNOPSIS OF THE CLASSES AND ORDERS OF ZYGOPHYTA.

- I. Cell walls impregnated with silica, composed of two valves. Subphylum and class, DIATOMEÆ. Diatoms.
 - A. Valves with a raphe or pseudo-raphé or with a sagittal line, with a zygomorphic or insobilateral or sometimes irregular symmetry; never centric; valve-view mostly boat-shaped (naviculoid), rod-shaped, needle-shaped, or elliptic in outline; motile or non-motile; conjugation known in most groups. Mostly fresh water plants.
 - Naviculales*. Long Diatoms
 - B. Valves without a raphe or pseudo-raphé, with a concentric or radiating symmetry around a central point, valve-view usually circular, polygonal, or broadly elliptical in outline, rarely boat-shaped or irregular; conjugation unknown; cells without spontaneous movement. Mostly marine plants. *Eupodiscales*. Round Diatoms.
- II. Cell walls without silica but with abundant development of gelatinous pectose, causing the plants to be slimy to the touch. Subphylum and class, CONJUGATÆ.
 - A. Thallus a filament, or commonly separating into single cells, mostly flattened, the cell wall divided into two symmetrical halves; cells mostly constricted at the middle, often of fantastic and beautiful form; cell contents mostly divided into symmetrical halves; conjugation by the breaking open of the cell walls or by the formation of a primitive conjugation tube. Fresh water algæ. *Desmidiæ*. Desmids.
 - B. Thallus a simple filament, or occasionally with rhizoid-like outgrowths, with cylindrical cells, the cells not constricted in the middle, but sometimes the contents divided into symmetrical halves; these latter forms distinguished from the preceding order by the definite filament and prominent conjugation tube; some species forming aplanospores. In fresh and brackish water. *Zygnematales*. Pond-scums.

SYNOPSIS OF THE CLASSES AND ORDERS OF GONIDIOPHYTA.

- I. Plants unicellular or colonial, not truly filamentous.
 - A. Nonsexual, unicellular or colonial algæ without zoospores, commonly with autospores; cells normally with one nucleus. AUTOSPORÆ. Primitive Green Algæ.
 - 1. Reproduction by autospores, the protoplast dividing within the mother cell, and the daughter cells escaping singly or in colonies. In fresh, brackish, or sea water, or on moist rocks, etc.; some endozoic in water animals. *Selenastrales*.
 - 2. Reproduction by vegetative division and separation by splitting of the daughter cells. Aerial, on damp-stones, trees, etc., or in fresh or salt water. *Protococcales*. (Pleurococcales).
 - B. Sexual primitive, parasitic or occasionally saprophytic, aquatic or aerial fungi, or perhaps some nonsexual. ARCHEMYCETÆ. Primitive Fungi.
 - 1. Ameboid zoospores uniting into plasmodial masses; plants holocarpic; zoospores with one flagellum; parasitic in the roots of higher plants. *Plasmodiophorales*. Clubroot Fungi.

2. Zoospores not uniting to form a plasmodium, with one or sometimes two flagella.
 - a. Plant body holocarpic, the whole forming a fructification; rhizoid-like processes, if present, without nuclei. *Chytridiales*.
 - b. Plant body eucarpic, forming an imperfect mycelium-like filament, divided into principal and secondary axes. *Cladochytriales*.
- C. Isogamous or heterogamous, sexual algæ or probable derivatives from them, with zoospores.
 1. Unicellular or colonial algæ, usually with one nucleus in each cell rarely cenocytic, the colonial forms not produced by the symmetrical aggregation of free zoospores; vegetative stage non-motile or active; isogamous or heterogamous. *CHLOROCOCCEÆ*.
 - a. Cells ciliated and motile in the vegetative state; unicellular or in definite colonies. *Volvocales*.
 - b. Cells not active in the vegetative stage.
 - (a) Vegetative cell divisions absent, cells separate or somewhat cenocytic. *Chlorococcales*.
 - (b) Colonies increasing by vegetative cell division. *Tetrasporales*.
 2. Cenocytic algæ consisting of colonies of peculiar form, new colonies being produced by the definite arrangement of daughter cells developed in the parent cenocyte; isogamous, aquatic. *HYDRODICTYÆ*. One order, *Hydrodictyales*.
- II. Green algæ or aquatic fungi with a filamentous or massive body and 1, 2, 4, or many cilia on the zoospores and gametes.
 - A. Cenocytic, septate or nonseptate, isogamous or heterogamous.
 1. Algæ usually pure green in color.
 - a. Vegetative body usually septate, consisting of a series of cenocytes; chloroplasts forming a net, rarely in separate plates. *SIPHONOCLEADÆ*. Lower Tube Algæ.
 - (a) Plants isogamous or slightly heterogamous; filaments branched. *Cladophorales*.
 - (b) Plants heterogamous, with stationary eggs and motile spermatozooids; filaments septate, unbranched, free-floating. *Sphaeropleales*.
 - b. Vegetative body usually nonseptate, with distinct lenticular, oval, or plate-like chloroplasts. *SIPHONÆ*. Higher Tube Algæ.
 - (a) Sexual reproduction unknown or isogamous, the gametes sometimes of unequal size.
 - ((a)) Small globular terrestrial plants with branched rhizoids penetrating the ground; zoospores with cilia of unequal lengths. *Botrydiales*.
 - ((b)) Mostly large marine or sometimes endophytic algæ; zoospores if present not with unequal cilia. *Bryopsidales*.
 - (b) Sexual reproduction by highly specialized stationary eggs and motile spermatozooids; thallus tubular, branched or unbranched, growing in fresh or brackish water or on moist soil. *Vaucheriales*.
 2. Filamentous, saprophytic, aquatic fungi with stationary eggs and unciliated spermatozooids. *MONOBLEPHARIDÆ*. One order, *Monoblepharidales*.
 - B. Algæ having normal vegetative cells with one nucleus, with a conjugation of free-swimming gametes, or with motile sperms and stationary eggs. *CONFERVÆ*. *Confervas*.
 - (A) Isogamous, or the free-swimming gametes sometimes of unequal size.
 1. Thallus unbranched.
 - (1) Chloroplasts reticulate, without pyrenoids; fresh water plants. *Microsporales*.
 - (2) Chloroplasts central or parietal, with one or more pyrenoids.

- a. Chloroplast single, central, stellate, with one pyrenoid; no zoospores known; aerial in habit. *Prasiolales*.
- b. Chloroplasts parietal, with one to many pyrenoids.
 - (a) Unbranched filaments; chloroplasts with one to many pyrenoids. *Ulotrichales*.
 - (b) Thallus expanded, a 1-2-layered plane or tube; chloroplast single with one pyrenoid; mostly marine. *Ulvales*.
- 2. Thallus filamentous, branched, usually abundantly so, the branches often with attenuated or hair-like tips. *Chaetophorales*.
- B. Heterogamous, the egg stationary in the oogonium, sometimes with dwarf males as an intercalated phase.
 - 1. Oogonium not developing a cortical layer after fertilization. *Oedogoniales*.
 - 2. Oogonium with a trichogyne-like tip, and covered after fertilization by a cortical layer; thallus disk-like or cushion-like. *Coleochaetales*.

SYNOPSIS OF THE CLASSES AND ORDERS OF PHAEOPHYTA.

- I. Zoospores when present and ciliated gametes with two flagella; if with an alternation of generations, then the gametophyte minute.
 - A. Gametangia plurilocular; zoospores produced in unilocular sporangia; apparently without an alternation of generations. PHAEOSPORÆ. Little Kelps.
 - 1. Frond mostly filiform; zoospores and isogametes similar, rarely with gametes of unequal size. *Ectocarpales*.
 - 2. Frond flat and leathery, with filamentous branches; heterogamous, with micro- and mega-gametes, both motile; zoospores on diploid individuals (?). *Cutleriales*
 - B. Gametangia unilocular or unicellular; zoospores none, or when present produced in unilocular sporangia and giving rise to minute male and female gametophytes.
 - 1. With a simple diploid sexual cycle and without zoospores; gametangia unilocular; eggs large and non-motile, but discharged from the oogonium; sperms minute and free-swimming. *CYCLOSPORÆ*. Rockweeds.
 - 2. With an alternation of generations; nonsexual zoospores produced in unilocular sporangia and giving rise to small male and female gametophytes; gametangia unicellular; sporophyte often very large. LAMINARIÆ. Giant Kelps.
 - One order, *Fucales*.
- II. Nonsexual spores non-motile; sperms with one flagellum; reproductive organs external; with a regular alternation of prominent sexual and non-sexual generations. DICTYOTÆ. One order, *Dictyotales*.

SYNOPSIS OF THE CLASSES AND ORDERS OF RHODOPHYTA.

- I. Nonsexual reproduction by single thallus cells, trichogyne imperfectly developed; no pits between the thallus cells. MONOSPORÆ.
 - One order, *Bangiales*.
- II. Nonsexual reproduction by tetraspores usually developed in groups of four; trichogyne well developed; cells protoplasmically connected through large pits in the walls. FLORIDÆ.
 - A. Sporophores ("Gonimoblasts" or branches bearing the carpspores) of the sporocarp produced directly from the fertilized oogonium; mostly plants with filiform fronds. Fresh water or marine. *Nemalionales*.
 - B. Sporophores produced by auxiliary cells after these conjugate with the fertilized oogonia or their branching processes (ooblastema).

1. Sporophores produced by nearby auxiliary cells. Marine plants.
 - a. Sporophores produced by nearby auxiliary cells and growing outward in the plant body; filiform, foliaceous, or massive plants. *Rhodymeniales*.
 - b. Sporophores produced by the nearby auxiliary cells and branching copiously in the surrounding tissues of the plant body; fronds parenchymatous, erect or spreading, branching, cylindrical, flattened, or leaflike. *Gigartinales*.
2. Sporophores produced by remote auxiliary cells after these have conjugated with the branched "ooblastema" filaments arising from the fertilized oogonium, fronds filiform, branched, often flattened. Mostly marine, but a few fresh water species. *Cryptonemiales*.

PHYLUM, CHAROPHYTA.

One class and one order, CHAREÆ. *Charales*. Stoneworts.

THE TWO SUBPHYLA OF MYCOPHYTA.

- I. Plants with a cenocytic mycelium, without or with transverse septa. *PHYCOMYCETÆ*. Algal Fungi.
- II. Plants with a septate mycelium, the vegetative cells containing one or two nuclei; normally with a conjugate phase in the life cycle. *MYCOMYCETÆ*. Higher Fungi.

SYNOPSIS OF THE CLASSES AND ORDERS OF PHYCOMYCETÆ.

- I. Sexual spores, "zygospores," produced by the union of the contents of two similar or nearly similar conjugating branches of the mycelium, the one branch not penetrating the other; nonsexual spores rarely zoospores. Saprophytes or animal parasites, a few parasitic on other plants. *ZYGOMYCETÆ*.
 - A. Nonsexual spores motile, with one flagellum, in terminal sporangia. Saprophytic, aquatic plants growing on dead insects. *Zygochytiriales*.
 - B. Nonsexual spores nonmotile, in sporangia or abstricted conidia; saprophytic or occasionally parasitic on other molds or on higher plants. *Mucorales*. Common Molds.
 - C. Nonsexual spores nonmotile, single at the ends of conidiophores; mostly parasitic on insects, as flies, grasshoppers, plant lice, etc., rarely on plants. *Entomophthorales*. Insect-cholera Fungi.
- II. Sexual spores, "oospores," formed by the union of the contents of two conjugating branches of unequal size, the smaller usually penetrating the wall of the larger by means of a fertilization tube; or discharging its contents into it, sometimes parthenogenetic; nonsexual spores, either zoospores with one or two cilia, or conidia. Plant or animal parasites or saprophytic, sometimes aquatic. *OOMYCETÆ*.
 - A. Nonsexual reproduction not by conidia; mostly aquatic fungi; a few on higher aerial plants.
 1. Mycelium present but poorly developed, either free or endophytic parasites; oospores formed by the conjugation of a larger and a smaller branch of the mycelium, the contents of the smaller branch passing over into the larger. *Oochytriales*.
 2. Mycelium usually poorly developed, with septa; endophytic parasites, mostly in fresh water algæ, some in the roots of higher plants; sporangia producing zoospores. *Ancylistales*.
 3. Mycelium well developed; mostly aquatic molds; saprophytic or parasitic; nonsexual reproduction by zoospores, rarely by non-motile spores. *Saprolegniales*.
 - B. Nonsexual reproduction by aerial conidia, which may give rise to zoospores; mycelium parasitic in higher plants. *Peronosporales*.

THE TWO MAIN PHYLETIC BRANCHES OF THE MYCOMYCETÆ.

- I. With ascospores, commonly 8 in an ascus; conjugate phase present, but usually not prominent. Here are included also all conidial types whose perfect stage is not known. ASCOMYCETOUS GROUPS.
- II. With basidiospores, commonly 4, developed on a basidium; one prominent stage of the mycelium with two nuclei in each cell (conjugate phase); conidia sometimes produced, or spores of various types.

BASIDIOMYCETOUS GROUPS.

SYNOPSIS OF THE CLASSES AND ORDERS OF ASCOMYCETOUS FUNGI.

- I. Asci developed after the conjugation of two cells of the mycelium, or parthenogenetically (?); occasionally fertilization by means of detached conidia-like spermatia; nonsexual conidia usually produced. Saprophytes or parasites on plants or animals, with an ordinary mycelium; many lichen fungi. In many species only the conidial form is known.

ASCOMYCETÆ. Sack Fungi.

- (I) Ascus stage known, conidial stage also commonly present.

- A. Asci not in a definite fruiting body, with a variable number of spores or with a definite number.

PROTO-ASCOMYCETÆ. Lower Sack Fungi.

1. Plants developing a more or less typical mycelium.
 - a. Asci not arising from chlamydospores, (gemmæ), single or scattered, sometimes many-spored, thus resembling ordinary sporangia. *Endomycetales*.
 - b. Asci arising from intercalary chlamydospores (gemmæ), ellipsoidal or elongated. *Taphrinales* (Exoascales).
2. No typical mycelium usually developed; asci entirely isolated; vegetative reproduction by budding of the cells; plants producing alcoholic fermentation.

Saccharomycetales. Yeast Plants.

- B. Asci with a definite number of spores, in typical cases commonly 4 or 8, collected on or in an ascocarp.

- (A) Asci arranged at different levels in the fruiting body or fasciculate and surrounded by a spherical, cylindrical, pyriform, or shield-like wall which is commonly perforated at the top, but sometimes completely closed.

1. Asci arranged at different levels in the fruiting body; or the hymenium lining cavities; mostly mold-like or tuber-like fungi. PLECTOMYCETÆ. Little Tuber Fungi.

One order, *Aspergillales*.

2. Asci in fascicles arising from a common level in a perithecium or cleistothecium or under a shield-like wall, mostly of a dark color. PYRENOMYCETÆ. Black Fungi.

- (1) Saprophytes, or parasites on higher plants, not symbiotic with algæ.

- a. Cleistothecia globose, scattered, without apparent ostiole in the top; superficial parasites in leaves, stems, etc. *Pertisporiales*. Powdery Mildews.
- b. Perithecia typically with a distinct ostiole; commonly situated in a stroma.

- (a) Perithecia, and stroma if present, fleshy or membranous, bright-colored, as white, yellowish, red, or blue. *Hypocreales*.

- (b) Perithecia, and stroma if present, hardened, never fleshy, rarely membranous; dark-colored, as black or dark brown.

- ((a)) Walls of the perithecia scarcely distinguishable from the stroma. *Dothideales*.

- ((b)) Perithecia with distinct walls, either free or imbedded in a stroma. *Sphaeriales*.

- (c) Perithecia membranous to leathery, long enclosed in a covering which ruptures by a radiating or stellate fissure or by a slit at maturity.
 ((a)) Perithecia rupturing by a stellate opening.....*Phacidiales*.
 ((b)) Perithecia opening by a slit.
Hysteriales. Slit Fungi.
- (2) Helotic fungi living symbiotically with algæ, forming lichens.....*Pyrenulales*.
- (B) Asci collected in a flattened concave, convex, or irregular hymenial layer; fruiting body (ascoma) a disk-like or cup-like apothecium or at first closed and opening at maturity, the hymenial layer sometimes becoming pulverulent; sometimes prominently stalked.....*Discomycetæ*. Disk Fungi.
1. Ascoma mostly elongated, or if round then becoming pulverulent, the spores and paraphyses forming a powdery mass.
 - a. Apothecia sphaeroidal, forming a powdery mass when mature, saprophytes or lichen fungi. *Caliciales*.
 - b. Apothecia linear, ellipsoidal or somewhat angular; lichen fungi symbiotic with algæ belonging to the Gonidiophyta.....*Graphidales*. Black Lichens.
 2. Ascoma mostly round or irregular, not becoming pulverulent.
 - (1) Ascoma not permanently hypogaeous.
 - a. Lichen fungi with circular apothecia, symbiotic with algæ belonging to the Gonidiophyta and to the Cyanophyceæ....*Lecanorales*. Disk Lichens.
 - b. Ordinary fungi, sometimes large, with fleshy or leathery bodies, or in the simpler forms the fruiting body only slightly developed; ascoma at length becoming cup-shaped or saucer-shaped, or developing into a convex and sometimes pitted head on a stalk, some of the primitive forms merely developing a flat open plate.
 - (a) Asci inoperculate, opening by an irregular rupture at the tip, texture usually tough to leathery; spores mostly comparatively small or slender and often multicellular.
Geoglossales.
 - (b) Asci operculate, opening by a definite lid or by a transverse or diagonal slit at the top; texture fleshy; spores comparatively large, unicellular.....*Pezizales*. Cup Fungi.
 - (2) Ascoma hypogaeous and fleshy, the hymenium lining cavities, permanently enclosed or finally opening. These plants show some resemblance to members of the Plectomycetæ and might belong to that series..
Tuberales. Truffles.
- (II) Ascus stage not known, the hyphæ bearing conidia only and isolated conidial stages whose Asci are known; imperfect fungi with conidia superficial or in pycnidia, borne on loose innate hyphæ. A provisional subclass for conidial forms with uninucleate cells.
DEUTEROMYCETÆ. Imperfect Fungi.
- A. Conidia developed upon separate conidiophores which do not form a stroma; parasites and saprophytes.....*Moniliales*.
 - B. Conidia developed on a stroma; mostly saprophytes, a few destructive plant parasites.....*Melanconiales*.
 - C. Conidia developed in pycnidia; parasites and saprophytes.
Sphaeropsidales.

- II. Asci developed after fertilization by means of a trichogyne and spermatium, no conidia known, but the spermatia sometimes conidium-like; minute fungi with a peculiar vegetative body parasitic on various insects, especially water beetles. LABOULBENIÆ. Beetle Fungi.
- A. Sperm cells produced in closed antheridia. *Laboulbeniales*.
- B. Sperm cells produced like conidia, terminally or laterally on appendages. *Ceratomyceales*.

SYNOPSIS OF THE CLASSES AND ORDERS OF BASIDIOMYCETOUS FUNGI.

- I. Basidia arising from teliospores; often other types of spores also produced; plant parasites, often heterecious; conjugate phase often prominently developed. TELIOSPORÆ. Brand Fungi.
- A. Teliospores usually black, not stalked, produced in ovularies, leaves, or stems of the host.
1. Teliospores developing a nonseptate basidium which bears the spores at the apex. *Tilletiales*. Stinking Smuts.
 2. Teliospores developing a several-celled or septate basidium which bears the spores at the sides of the cells. *Ustilaginales*. Smuts.
- B. Teliospores usually stalked, producing black or brown pustules under the epidermis of leaves or stems; often producing, on the same or on a different host, clusters of cup-like or crater-like aecia with spores formed in chains inside of a membranous pseudoperidium; other spore types may be present as uredospores and pycniospores. *Uredinales*. Rust.
- II. Basidia produced directly on the vegetative mycelium, no proper teliospores being present, mostly saprophytes but some parasitic, especially on trees; often with massive fruiting bodies; conjugate phase prominently developed, with clamp-connections; terrestrial or epixylous; a few lichen fungi. Here are included the sterile mycelia known as mycorrhiza. BASIDIOMYCETÆ. Basidium Fungi.
- A. Basidia septate transversely or longitudinally, or sometimes merely deeply two-forked; fruiting body mostly gelatinous; saprophytes.
- PROTOBASIDIÆ.
1. Basidia with transverse septa. *Auriculariales*. Ear Fungi.
 2. Basidia divided by diagonal or vertical septa. *Tremellales*. Jelly Fungi.
 3. Basidia long clavate, divided at the summit into two long sterigmata; spores divided before germination proper; mostly small saprophytes. *Dacryomycetales*.
- B. Basidia nonseptate.
1. Basidia on a distinct membranous hymenium exposed from the beginning or at first covered and finally naked, covering gills, pores, spines, or a smooth or wrinkled surface; rarely parasitic and without a special fruiting body, the basidia then arising out of the epidermis of the host plant. HYMENOMYCETÆ.
 - a. Without a definite fruiting body. *Exobasidiales*.
 - b. Usually with a definite fruiting body, the basidia on a distinct membranous hymenium, covering gills, pores, spines, or a smooth or wrinkled surface. *Agaricales*. 2. Basidia enclosed within a definite peridium but sometimes exposed at maturity, the spores then borne in more or less deliquescent gleba. GASTEROMYCETÆ.
 - (1) Fruiting body not dehiscing in such a manner as to expose the hymenium by emerging from the peridium, nor developing sporangioles attached to the peridium wall with cords.
 - a. Fruiting body not developing a hyphal capillitium, but remaining fleshy until the spores are mature, or becoming pulverulent.
 - (a) Fruiting body large, tuberous, fleshy, subterranean, with internal hymenium which lines the walls of cavities. *Hymenogastreales*. False Truffles.

- (b) Fruiting body small to large, becoming pulverulent; basidia uniformly distributed through the fruiting body or forming skein-like masses.
Sclerodermatales. Thick-skinned Puff-balls.
- b. Fruiting body, when mature, filled with dust-like spores mixed with the hyphal capillitium. *Lycoperdales*. Puff-balls.
- (2) Fruiting body breaking open and the spore-bearing part or gleba emerging or else developing sporangioles, attached by threads to the wall of the peridium.
 - a. Fruiting body small, leathery, spherial or top-shaped developing sporangioles. . . . *Nidulariales*. Birds-nest Fungi.
 - b. Fruiting body fleshy, at first tuberous and subterranean, but later the spore-bearing interior or gleba emerging from the peridium by an elastically expanding stalk; usually ill-smelling. *Phallales*. Stink-horns.

AN EXAMPLE OF SEDIMENTS DEFORMED BY ICE THRUST¹.

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Crumpling due to the drag of moving ice over more or less unconsolidated sediments has been described from various regions heretofore.² The present note desires to set on record a case of deformation in which the Ohio shale of the Devonian was one of the rocks affected and in which the method appears to have been actual shove by the ice-sheet at, or near, its front.

The exposure existed for several days in the pit of the Shale-Brick Company located in northeast Columbus. The deformed mass rested at the time against a solid wall of shale on the south and southeast, while to the north of the location there exists a valley in the shale, more than 50 feet deep, filled with chocolate clay of unknown depth overlain by drift up to 30 or more feet thick. The materials affected by the deformation included bedded shale at the base and weathered shale, chocolate clay, and drift above.

Two items merit notice: the direction of the ice thrust and the response of the materials to deformation. All observations at the time of the exposure indicated that the effective thrust of the ice came from the northwest. If local eddies of sharp outline could exist in ice as readily as in water the direction of ice thrust would arouse little comment. Topographic details of the underlying rock might deflect portions of the marginal ice, but to do so to the extent of 45 degrees or more and permit thrust sufficient to cause the observed deformation is doubtful.

¹Read before the Ohio Academy of Science, Springfield, April 27, 1929. The writer is indebted to Mr. John Stout, who directed attention to the exposure here described.

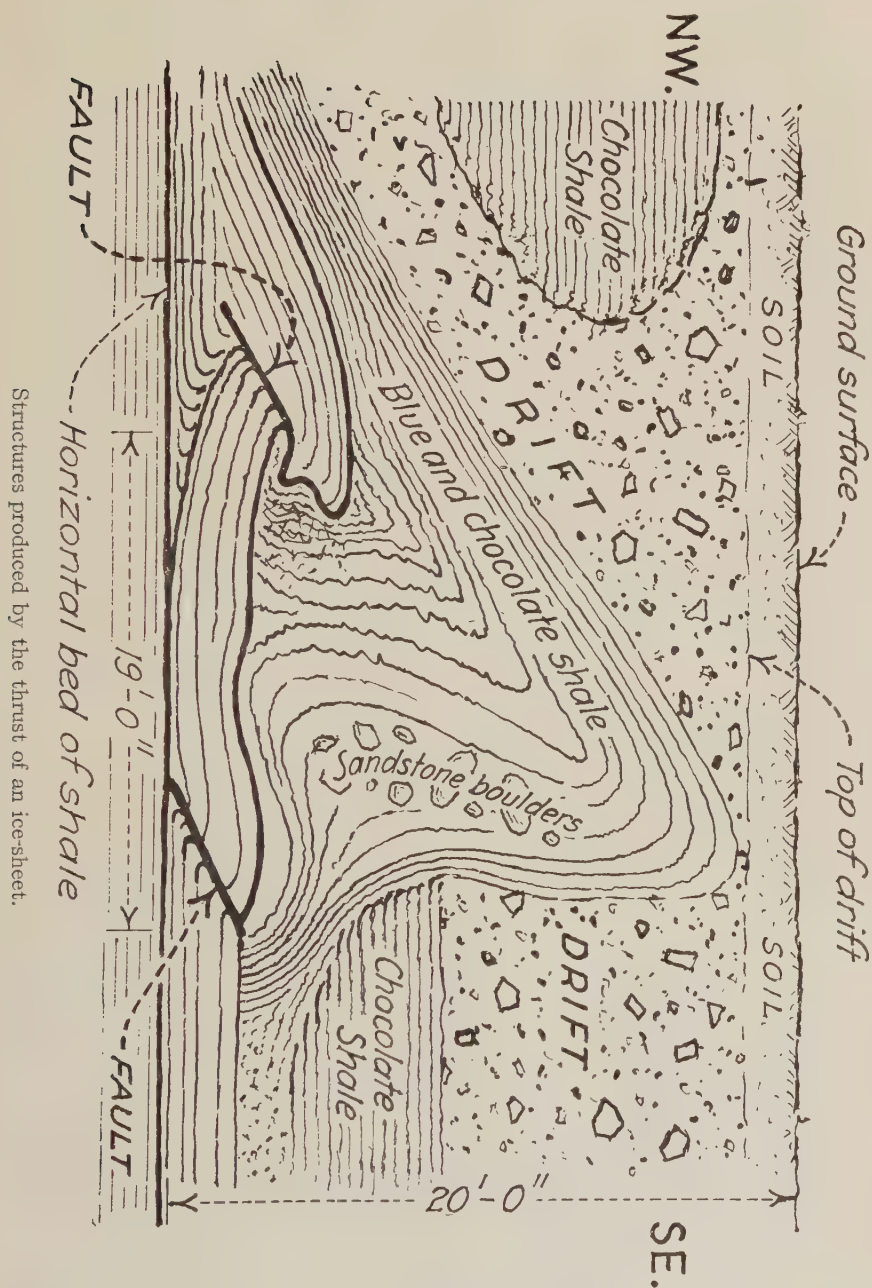
²Shaler, N. S. 1890. Tertiary and Cretaceous deposits of eastern Massachusetts. *Bull. Geol. Soc. Amer.*, Vol. 1, 443-452.

Woodworth, J. B. 1897. Unconformities of Marthas Vineyard and of Black Island. *Bull. Geol. Soc. Amer.*, Vol. 8, 197-212.

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Lahee, F. H. 1914. Contemporaneous deformation: a criterion of aqueo-glacial sedimentation. *Jour. Geol.*, Vol. 22, 786-790.

Fuller, Myron L. 1914. The geology of Long Island, New York. *U. S. Geol. Survey, Prof. Paper* 82.



The northwest direction meets difficulty when the attempt is made to harmonize it with the character of the ice lobes and direction of ice movement as shown on plate V, monograph LIII³ of the United States Geological Survey, especially in view of the geographic location of the deformed mass in relation to the axis of the Scioto-Olentangy basin. If the direction was typical of the given locality when the front of the ice stood there it would indicate that the Scioto lobe of the Wisconsin glacier deployed first over the western part of the Scioto basin and thence spread eastward. The axis of ice activity and advance, for a time at least, lay to the westward of the Scioto-Olentangy drainage axis, a condition favored by the topography of the basin whose cross-profile is asymmetrical in regard to a shorter and steeper eastern slope. The areal distribution of the Powell morainic belt likewise suggests a greater deployment of the ice in the western sector of the Scioto lobe.

However, the orientation of the deformed mass, the nature of the materials, and certain chemical criteria (striking variation in Ca CO_3 content) which cannot be detailed at present suggest that the deformation was accomplished by a pre-Wisconsin ice sheet. In this connection it is interesting to note Leverett's⁴ reference to an Illinoian or possible pre-Illinoian advance apparently from the Lake Superior region.

The materials of the deformed mass reacted to the pressure in an interesting and characteristic fashion. The more competent beds at the base, the Ohio shale, yielded by fracture which resulted in three faults, two overthrusts and one underthrust. The less competent chocolate clays (labelled shale on the chart) were squeezed into an overturned fold with thinning on the limbs. The chocolate clays, which underlie the drift unless disturbed subsequent to formation, are an extremely tenaceous, gummy, apparently laminated material deposited in quiet waters near the bottom of a rock-walled valley. Cobbles scattered sparsely throughout the clay suggest transportation by means of floating ice.

³Leverett, Frank. 1915. The Pleistocene of Indiana and Michigan and the history of the Great Lakes. U. S. Geol. Survey, Mono. LIII, Plate V.

⁴Ibid, 63-64.

DECEREBRATION OF THE DOMESTIC FOWL.

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The decerebration of the pigeon has been successfully accomplished by numerous investigators. Rolando (1809), Flourens (1822), Munk (1883), Shrader (1889), Rogers (1916 and 1922-23), and others have contributed much to our knowledge of the operative technique and the resultant behavior of the decerebrate bird. Rolando (1809) showed that decerebrate pigeons could be kept alive for a long period of time after extensive destruction of the cerebrum, the birds exhibiting a sleep-like attitude until they were destroyed.

Flourens (1822) decerebrated pigeons and chickens. After the result of his experimental work, he concluded that the seat of intelligence, will, etc., was in the cerebrum; that the senses, reception and conveying of the sense impressions were entirely separate; e.g. the sense of sight in the corpora bigemina. The decerebrate animal could not use its senses because it lacked perception.

In contrast to these workers Shrader (1889) stated, "None of my observation birds have showed longer than the first three or four days, that sleep-like attitude." He observed that decerebrate pigeons did not feed since this act apparently depended on portions of the frontal brain or perhaps on parts of the middle brain.

Munk (1883) studying the functions of the cerebral cortex of pigeons states, "I cannot agree with the oft repeated recommendation to use young animals. I have had the best success with older pigeons and finally used older ones for the experiment. * * * * * I must give warning against preparing the birds through long starvation and thirst to decrease hemorrhage, because as a result of such procedure the animal has not enough resistance and easily collapses from weakness. It is enough to keep nourishment away for eighteen hours."

The ability of an apparently decerebrate bird to regain the complex reflexes of eating and drinking was studied by Munk (1883) and Shrader (1889). These workers concluded that basal parts of the corpora striata were present. In a recent

work, Rogers (1922-1923) states, "The following basal areas of the striatum were demonstrated histologically to be present, though reduced in size; meso-striatum and parts of the ekto-striatum and epi-striatum. These parts were connected with the thalamus and mid-brain by medullated fibres which, after death, were readily stainable, and seemed histologically to be normal. These parts were present in one hemisphere only, only traces of the other hemisphere being present."

In the present series of decerebrations, the method of operative procedure closely followed that of previous workers, the technique being modified slightly as occasion demanded. Extended over a period of two years, fifty-four birds were operated removing the cerebral hemisphere partially or completely. Fowls were selected that were about one year of age and free from disease. These were placed in cages 20" x 20" x 12", each bird having a separate compartment.

OPERATIVE PROCEDURE.

Birds were fasted eighteen to twenty-four hours before operating. The hen was secured in a cloth sack, leaving the head and neck protruding. Squibb's anaesthetic ether was used to anaesthetize the bird. Feathers were plucked from the operative area from ear to ear and from the comb posteriorly to the first cervical vertebra. A transverse incision was made through the skin from ear to ear and the periosteum removed from the bones covering the cerebral hemispheres. Two holes were trephined over the center of each hemisphere, and with small bone forceps the openings were enlarged from before backwards and from side to side, care being taken not to injure the dura mater, also carefully avoiding the longitudinal sinus. The dura mater was slit antero-posteriorly, after applying a solution of codrenin (cocaine 2% solution, with adrenalin 1-15000) to control hemorrhage. Using a small spatula the cerebral hemispheres were lifted, care being taken not to injure the brain stem. After the hemispheres were removed, hemorrhage was checked by using pledgets of cotton moistened with codrenin. The control of hemorrhage is more of a problem in fowls than in pigeons, due to the larger blood supply to these parts in the former. No attempt was made to suture the dura mater or the skin, in fact the latter was purposely left unsutured, so that the blood clot would not cause pressure upon basal centers. No ill results occurred from

infection, because of the high resistance that birds possess. Direct observations were not made until three or four weeks elapsed, thus giving time for the disturbed parts to heal.

Since the fowl could be completely decerebrated and continue in health for one month, the question arose, how long could a decerebrate bird live. Three operated fowls were selected, their behavior indicating complete decerebration. Since the eating and drinking reflexes were destroyed, food and water were administered by forced feeding to these birds daily. Two were observed over a period of four months, before being destroyed and autopsied. The third bird was kept in health for eight months, at which time it was attacked and killed by a rat, thus putting an end to the observation.

BEHAVIOR OF DECEREBRATE BIRDS.

The behavior of the birds depends entirely upon whether the birds are partially or completely decerebrate. Immediately after the operation and for two or three days all birds show more or less shock. After this period, if the bird is only partially decerebrate, eating and drinking may be accomplished with some difficulty, the bird pecking at food much the same as young chicks do. Completely decerebrate hens present the typical picture given by similarly operated pigeons; sleepy attitude, head and neck drawn into body, feathers fluffed, with occasional stretching of neck and legs. If enclosed in a small cage scarcely any movements occur for hours. Placed in larger quarters, the birds would sometimes stand motionless for variable lengths of time, then suddenly move several steps. Never do they fall over obstructions purposely put in their paths. There seemed to be more or less direct relation between restlessness and a state of hunger or thirst. Feeding and watering invariably put an end to the aimless wanderings, the birds assuming the sleeplike attitude so characteristic of the well-fed and watered decerebrate bird. Not infrequently these birds that have been fed and watered will arouse from lethargy, make a few restless movements, defecate, and again lapse into a somnolent attitude. Thus it appears that hunger, thirst and visceral impulses are the main factors which cause restlessness in the decerebrate bird. On the whole, birds evidence much more activity when given spacious quarters than when confined in smaller cages.

The thalamus was injured or destroyed in four birds producing such effects as were described by Rogers (1919-20). There was some variation in these birds, but he describes the picture essentially presented as follows: "The feathers lay somewhat against the body, instead of fluffed; no spontaneous

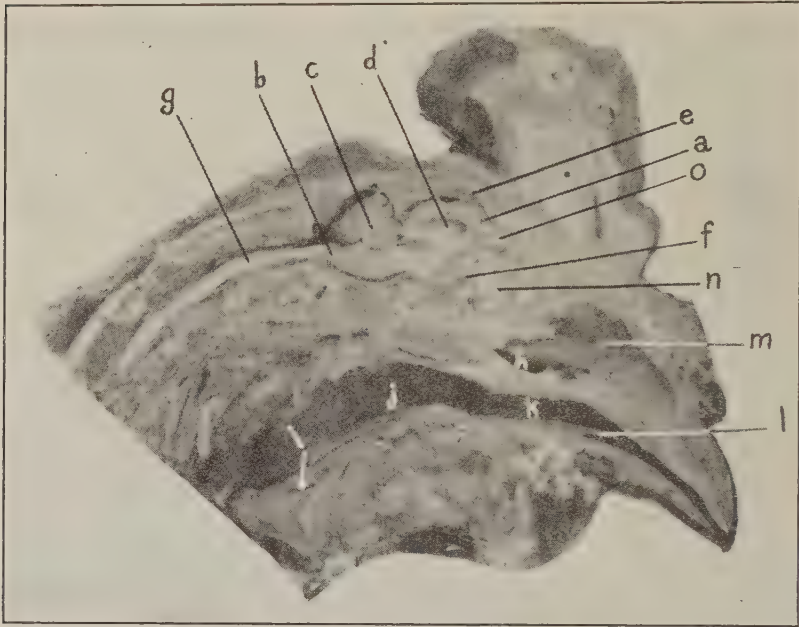


FIG. 1. Sagittal Section of the Head of Normal Birds.

a, cerebrum; b, medulla oblongata; c, cerebellum; d, lateral ventricle; e, dura mater; f, optic nerve; g, portion of cervical part of spinal cord; h, nasal cavity; i, arrow points to laryngeal opening; j, pharynx; k, oral cavity; l, tongue; m, septum nasi; n, medial portion of eye; o, olfactory bulb.

movements were made; body temperature was subnormal in three of the birds; stasis of food in the digestive tract; weakness; mucous membranes cyanotic; resting on tail feathers. Death followed in two or three days."

AUTOPSY OF DECEREBRATE BIRDS.

After the observations were made the decerebrate birds were embalmed with a 15% solution of formaldehyde, this being introduced into the left or right jugular vein, using a sixteen gauge needle and a 30 cc. syringe. The digestive tract and general condition of the birds were observed during post mortem. The heads were severed, placed in a solution of

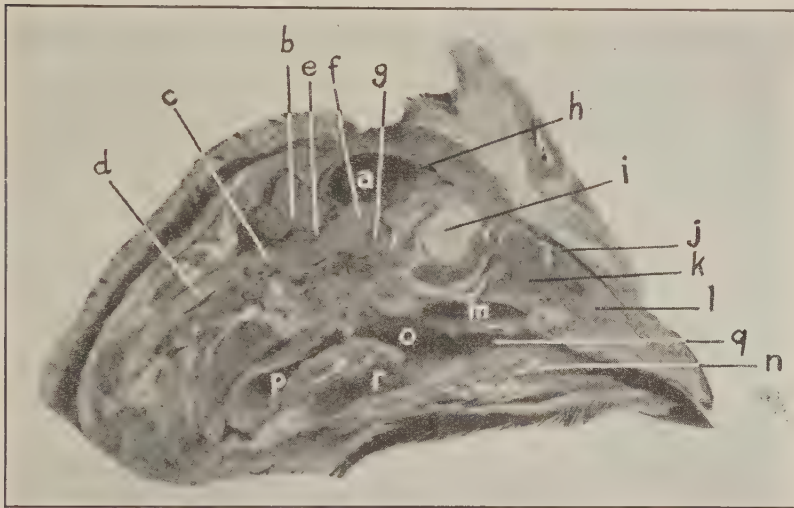


FIG. 2. Sagittal Section of the Head of Decerebrate Bird.

a, cerebral cavity; b, cerebellum; c, medulla oblongata; d, portion of cervical part of spinal cord; e, fourth ventricle; f, thalamus; g, optic nerve; h, dura mater; i, medial portion of eyeball; j, dorsal meatus; k, nasal septum; l, turbinate bone; m, posterior part of nasal cavity; n, tongue; o, pharynx; p, esophagus; q, oral cavity; r, larynx cranialis.

fuming nitric acid, one part of nitric acid to ten parts of water, and allowed to decalcify. In about ten days, the heads were sectioned and examined to determine definitely the areas of the brain tissue that had been extirpated. Figure I shows a sagittal section of the head of a normal bird, while Figure II shows a section through the head of a decerebrate bird. The cavity enclosed by the dura mater in Figure II was filled with clear cerebral fluid, this cavity communicating with the third ventricle by way of the inter-ventricular foramen.

In the birds that showed typical decerebrate attitude, it was found that the cerebral hemispheres were entirely removed, with the exception of small areas which had no connection with the brain stem. In other birds that gave evidence of only partial decerebration there were found variable quantities of cerebral cortex, apparently uninjured. The connections with the brain stem appeared to be undisturbed. Those birds that could eat and drink showed only a partial removal of the corpora striata.

SUMMARY.

1. In decerebration of the fowl care must be taken to prevent severe hemorrhage.

2. Leaving the dura mater and skin unsutured relieves pressure on the vital centers.

3. Fowls were completely decerebrated and kept in health for periods varying from two to eight months, there seems to be reason to believe that this time could be extended indefinitely.

4. The behavior of decerebrate fowls closely follows that of the decerebrate pigeon.

5. Birds which regain complex reflexes of eating and drinking showed the corpora striata intact.

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PRELIMINARY EXPERIMENTS ON THE JUMPING REACTIONS OF MELANOPLUS DIFFERENTIALIS UHLER

RAY T. EVERLY.

The problem was to determine the environmental factors affecting the jumping reaction of *Melanoplus differentialis* Uhler, the Differential Locust. Specimens were secured in the fields of the vicinity of the Ohio State University, where the experiments were conducted in the summer of 1925. No one factor was worked to the exclusion of the others, but light seemed to be the strongest stimulus. Owing to the lack of adequate apparatus and the short period of time in which the hoppers were available, no definite conclusions can be drawn at this time. This report is made public now in order to make available the methods used and the results obtained to others who might be interested in this problem.

These experiments were conducted under the direction of Dr. W. M. Barrows, of the Department of Zoology and Entomology, Ohio State University, to whom I am indebted for criticisms and suggestions. A large amount of time was spent in assembling and designing the apparatus and correcting it to offset several difficulties.

The apparatus consisted of two main divisions, the jump recording apparatus and the time recording apparatus. The former consisted of a cone of white cardboard, about two feet high, (I), (see diagram of apparatus), open at the top, which was covered with a piece of clear celluloid, (J). The base was tightly closed and light-proof, and was fastened to the platform of a scale used for weighing letters, (H). (This type of scale was used because of its high degree of sensitiveness). To the pointer of the scale was attached an arm, about 18" long, (G), which had a pin fixed through the free end. This pin recorded the jumps on the paper, blackened over a coal oil lamp flame, on the rotating cylinder of the recording instrument, (F). This cylinder was revolved by clockwork making a complete revolution every 18 hours. The timing apparatus consisted of a dry cell battery, a clock, with the crystal removed, a ringstand, and an electro-magnet. The negative wire from

the battery, (A), was grounded to the clock, (B). The positive wire was connected to the insulated post on the electro-magnet. From the other post on the electro-magnet a wire was connected to the clamp, (E), which was supported on the same ring-stand, (D), as the electro-magnet. This clamp held a piece of stiff flexible wire, tilted at an angle upward so that the minute hand of the clock would make a contact with it on the hour, closing the circuit, and after a few minutes would force the wire up and break the circuit, the wire returning to its former position. A small pointer on the electro-magnet was moved when the circuit was closed, thus recording the hours on a line on the rotating cylinder just above the line on which the jumps were recorded.

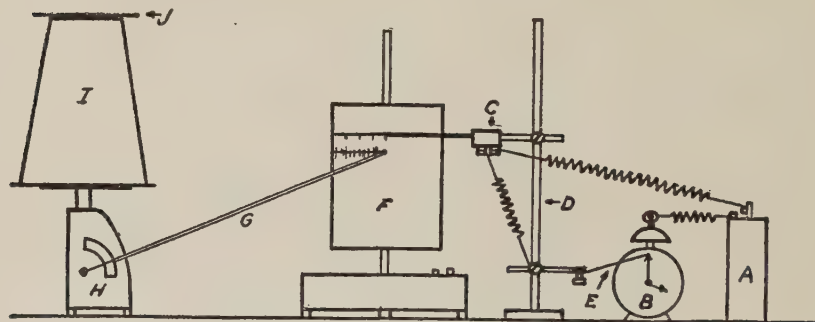


DIAGRAM OF APPARATUS

In all these experiments only one hopper was used at a time, and none were used for two successive periods. After 24 hours without food in the apparatus they were allowed a period of 24 hours for feeding and recuperation. Large cages were necessary as the grasshoppers confined in small ones were attacked and killed by the lawn ant, *Lasius niger americana* Em.

There were three types of experiments. First the insects were exposed to the diffused daylight in a room with an eastern exposure, about four feet from the window. No direct sunlight struck the insect. In this room there was a maximum variation of temperature of 12°F. occurring in the morning when the sun shone through the window. The humidity was rather constant, ranging from 43° to 50°F. in steps of 1°. The

following table shows the number of jumps per hour, correlated with the average temperature and average relative humidity, and light.

TABLE 1.

		P. M.												A. M.											
Hours		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
4 Grasshoppers	Light	Diffused Daylight												Dark											
	Jumps	7	12	3	6	10	15	27	46	3	1	1	6	2	1	0	0	1	2	4	11	19	16	18	17
	Ave. Hum.	43	43	44	44	44	44	45	46	46	47	48	48	48	48	49	49	49	49	50	50	50	49	49	49
	Ave. Temp.	76	76	75	75	75	75	75	75	75	74	74	74	74	74	74	74	73	73	73	74	74	85	77	75

The second type of experiment was run in the Department greenhouse, where there was a wide range of temperature and humidity, but the light was bright from 6:30 A. M. to 7 P. M. with perhaps a half hour of diffused light immediately preceding and following those hours. The changes in temperature were rather sudden, ranging from 89°F. to 62°F. Very little if any direct sunlight struck the insect or container as the glass was whitewashed to prevent destructive high temperatures. Table 2 shows the results obtained.

TABLE 2.

		P. M.												A. M.											
Hours		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
3 Grasshoppers	Light	Bright Daylight												Dark											
	Jumps	15	15	16	4	3	0	4	7	3	1	1	1	3	0	0	0	0	0	0	0	0	3	7	
	Ave. Hum.	49	43	46	48	50	53	57	62	66	68	69	69	69	70	71	71	71	71	73	74	75	67	50	45
	Ave. Temp.	80	80	82	80	78	76	75	73	71	70	69	68	67	66	65	65	63	63	64	64	65	70	77	82

The third type of experiment was conducted in a dark room where the temperature did not vary more than two degrees during any one period of 24 hours. However the

humidity was more variable, ranging from a variation of 4% in one experiment to 10% in the other. The light was supplied by a 40-watt Mazda lamp and was continuous. A record was kept of the sexes of the tested grasshoppers. Table 3 gives a comparison of the two sexes correlated with the temperature and relative humidity. The greater activity shown by the male does not necessarily indicate a difference in the activity of the two sexes as not enough of each sex were tested. It is natural to suppose that a greater activity would exist in

TABLE 3.

Hours	P. M.												A. M.											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Light	40 Watt Mazda Lamp - Continuous																							
3♂ Grasshoppers Av. Temp. Hum.	17	23	24	23	16	19	12	10	19	10	13	18	12	7	17	14	12	10	8	8	1	7	0	0
3♀ Grasshoppers Av. Temp. Hum.	60	60	58	57	57	57	58	59	59	59	59	60	60	60	60	59	59	60	60	60	59	58	57	56
3♂ Grasshoppers Av. Temp. Hum.	75	75	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	77
3♀ Grasshoppers Av. Temp. Hum.	0	0	8	15	6	8	6	5	9	0	0	1	1	0	0	1	4	7	3	14	11	8	2	4
3♂ Grasshoppers Av. Temp. Hum.	53	54	57	57	58	57	57	57	57	57	58	58	58	58	58	58	58	58	58	58	58	59	63	65
3♀ Grasshoppers Av. Temp. Hum.	68	68	68	68	68	68	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69

the male sex, if there was any difference at all. Many studies of animal life, where the sexes are differentiated into two separate individuals, shows a decided difference of habits and a greater activity on the part of the male, which is the aggressor. Further experiments may prove that this is also true of the saltatorial reactions of the grasshopper.

One variation of the above experiment was tried. Two different intensities and qualities of light source were used. In both cases the light was continuous for a period of 24 hours. Table 4 shows the results, with the temperatures and relative humidity recorded.

There seems to be little if any difference with the two different lights. Jumping is almost continuous throughout the

experiments, with the exception of one hour. With the lower-powered light the activity is greater and the jumps are more evenly distributed throughout the entire period. This corresponds with the results recorded in Table 1, where the period of greatest activity occurs when the light is at a minimum intensity, just preceding sunrise and following sunset. The conflicting results in Table 2 may be due to the modifying action of the temperature and humidity. Further experimentation is necessary to prove or disprove this theory.

TABLE 4.

		P. M.												A. M.											
Hours		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
4 Grasshoppers	Light	40 Watt Mazda Lamp - Continuous																							
	Jumps	17	23	32	39	33	33	19	18	29	11	14	24	18	11	21	17	17	19	14	26	17	22	8	14
	Av. Hum.	53	53	54	53	54	53	54	55	55	55	56	57	57	57	57	57	57	57	57	57	57	58	59	59
	Av. Temp.	71	71	78	78	79	79	72	72	72	72	72	72	72	72	72	72	72	76	76	76	71	76	76	75
4 Grasshoppers	Light	125 Watt Nitrogen Daylight Lamp - Continuous																							
	Jumps	24	22	22	10	16	16	14	18	24	14	18	38	8	14	20	10	6	6	0	16	16	8	14	16
	Av. Hum.	65	64	65	66	66	66	67	67	67	68	68	68	68	68	68	67	67	67	63	61	61	62	64	65
	Av. Temp.	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	73	73	73	73	73	73

Table 5 shows the comparison of the reactions of the grasshoppers to natural daylight and those tested with artificial light. The average temperatures and average relative humidity are also recorded. The variation of jumps per hour is much greater under natural light than under artificial light, which is to be expected as there is a greater variation of the former during the different hours of the day, especially toward night and early in the morning. The rays at these periods are more or less horizontal and must penetrate more of the atmosphere, which tends to change the quality and intensity of light by filtering out some of the rays. It would be interesting

to test out the different colors of the spectrum to determine which rays have the greatest effect on the grasshoppers.

SUMMARY

As stated previously no definite conclusions may be drawn from the limited number of experiments performed. However, the results obtained permit of certain deductions.

TABLE 5.

	Hours	P.M.												A.M.											
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
8 Grasshoppers	Light	Daylight												Dark											
	Jumps	22	27	19	10	13	15	34	54	6	2	2	7	5	1	0	0	1	2	4	11	19	16	21	24
	Ave. Hum.	46	43	45	46	47	49	49	54	56	58	59	59	59	59	60	60	60	60	61	62	62	62	50	47
	Ave. Temp.	78	78	78	78	77	76	75	74	73	72	71	71	71	70	69	69	68	68	68	69	69	77	77	78
8 Grasshoppers	Light	Continuous Light																							
	Jumps	35	42	54	67	41	46	40	30	50	20	27	46	23	17	34	25	25	26	16	39	26	26	13	17
	Ave. Hum.	58	58	58	58	59	58	59	59	59	60	60	61	61	61	61	60	60	60	59	59	59	59	60	61
	Ave. Temp.	72	72	73	73	73	73	73	73	73	73	73	73	73	73	73	73	74	74	74	72	74	74	74	74

NOTE. All humidities recorded are relative.

All jumps recorded are totals for the individuals tested which tends to balance differences in individualistic behaviour.

1. Light appears to be the strongest stimulus. In Table 5 it will be seen that the hoppers exposed to continuous light showed not only a greater activity, but the jumps were more or less evenly distributed over the entire period of 24 hours. Those exposed to daylight alone showed the period of maximum activity during the daylight hours. Comparison of the hours from 8 P. M. to 6 A. M. gives support to the supposition that jumping is a light response. Casual observation of grasshoppers in their natural habitat also lends support to the theory that light or other visual stimuli are the chief stimuli.

In the evening when the light is less intense a greater activity was observed among the different species of grasshoppers. This may be due to both the intensity and quality of the light, as well as the direction.

2. Heat, in these experiments, does not appear to affect the jumping. In Table 2, as stated before, heat may be responsible for the conflicting results recorded, so modifying the activity that the greater number of jumps were recorded when the light was more intense. In Tables 1 and 3 the greatest activity was shown when the light was less intense.

Work by Geist on the heat sensitive areas of certain grasshoppers showed, in this species, a period of continuous jumping when the surface upon which the grasshopper rested was heated to a temperature high enough to raise the air temperature to 37°C.—about 98°F. This was undoubtedly due to stimulation from the surface upon which they were resting. Whether the same would also be true if only the surrounding air only were heated, is a question to be decided by further experimentation. However, such temperatures do not as a rule occur in the natural habitat of this species of grasshopper.

3. Sex may play an important part in the difference displayed in the activity of different individuals. Table 3 shows a greater number of jumps recorded for the male of the species, as would naturally be supposed to be the case.

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